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CONTENTS.

PAGE.

Operating Costs of Horse and Electric Delivery Wagons in New York City. By Geo. F. Sever and R. A. Fliess. June 28, 1899 509
Electric Automobiles. (Illustrated.) By Elmer A. Sperry. June 28, 1899 533
Discussion 549
Report of Committee on Resolutions 552
Associate Members Elected. August 23, 1899 554
Associate Members Elected and Transferred. September 27, 1899 555
Series Arc Lighting from Constant Current Transformers. (Illustrated.) By William Lispenard Robb. September 27, 1899 557
Discussion 565
Cost of Arc Lighting. (Illustrated.) By H. H. Walt. December 27, 1899 579
An American Pacific Cable. (Illustrated.) By George Owen Squier. December 27, 1899 605
Death Notices. Samuel Dana Greene. James Hamblet 627
Advertisements 628

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A paper presented at the 16th General Meeting of the American Institute of Electrical Engineers, Boston, June 28th, 1899, President Kennelly in the Chair.

OPERATING COSTS OF HORSE AND ELECTRIC DELIVERY WAGONS IN NEW YORK CITY.

BY G. F. SEVER AND R. A. FLIESS.

During the last three years many descriptive articles relating to the automobile, have appeared in the technical press, but up to the present time, there has been published no definite data which might be used to indicate whether or not electric operation possessed any advantages. Hence both the general, as well as the technical public, could form no definite opinion as to the benefits to be derived from the use, in any particular class of service, of either an electric or a horse system.

The purpose of this paper is to present the results of an investigation, carried on during the past year in the city of New York, of the operating costs of the horse and electric delivery service, as at present instituted by the large department stores. This investigation formed part of a graduation thesis in the Electrical Engineering Department of Columbia University.

The present status of the art does not permit of an exhaustive comparison, as some of the data now presented will probably be entirely altered by the rapid developments which are taking place, the art progressing quite similarly to that of the electric railway. That which can be done most successfully is to compare the cost of maintenance of the two above mentioned systems, and if to-day, an electrical system costs less to operate and keep than a horse system, it is simply a question of a short time as to the replacement of the horse by the electrical method. Of course in considering the economy of any system, depreciation enters largely as a factor; but, in case of any new system such as is under consideration, the determination of the

depreciation of any of the various parts or of the system as a whole, would be difficult and for its solution would require long continued service and close observation. Owing to the short time that the automobile has been in the field in commercial competition with the horse, it has been impossible to collect a sufficient amount of data on this point to make its introduction of value in drawing a comparison between the total operative costs of the two systems.

SECTION 1.

Some Data on Horse Delivery Service.

The work done by a horse in moving a vehicle over level ground, consists in overcoming resistance to motion due to friction; it may be conveniently expressed in foot-pounds. When grades are encountered, the number of foot-pounds of work performed in the same distance will increase. This additional work is necessary to overcome the force of gravity. When on a descending grade, the horse does work in resisting the tendency of the vehicle to accelerate. Hence, when in motion, the horse is continually doing work. The exact amount of work performed by a horse in a day is a very variable quantity. It depends upon many factors, some of which are:

1. Kinds of road surface—macadam, asphalt, etc.
2. The condition of roads traveled over.
3. Topography of the country passed through.
4. Nature of the load.
5. Distribution of the load on the wheels.
6. The horse itself.

The horse is not an automatic machine that can be designed to perform a given amount of work with a given efficiency. It is, on the contrary, a most variable and, at times, wilful source of motive power. The breed, state of health, temperament, environment, adaptation to the load, etc., affecting in a greater or less degree, the amount of work that can be performed in a day by any individual horse. Therefore the problem of determining the amount of work done by a horse, under any but very regular and systematic conditions, is one of great complexity. But under regular conditions, the amount of work performed may be quite closely approximated. It is proposed in this section to give the results obtained in an investigation which was undertaken to determine, as closely as possible, the average

amount of work performed daily by a certain lot of horses engaged in the delivery service of a large dry goods store in New York city.

It may be well to explain in some detail the exact nature of the work required of this class of horses. The large "department stores," as they are now called, have to keep in operation winter and summer, irrespective of the weather, a delivery service which must be as regular in the fulfilment of its functions as the local steam railroads and street railway systems are in the execution of their obligations. The nature of the service necessitates a highly organized system of delivery by means of small units capable of carrying 700 to 800 lbs., over short distances and with considerable speed. This problem has been met and solved by these stores through the introduction of a horse delivery service composed of many small units, each one of which has its special district to cover and a certain time schedule to follow.

To illustrate more clearly the method pursued, we will follow one of these units through its daily routine. Let us consider the case of a wagon making three deliveries a day. The first delivery starts from the stable at 8 o'clock in the morning and arrives at the store a few minutes later—the stable, in most cases being not far from the stores. Arrived at the store, the wagon receives its load, which varies from day to day, but which will average the year round, not over 800 lbs. This load may be taken as the average load on all trips as the wagon leaves the store. The load decreases as deliveries are made so that theoretically when the wagon has reached the store again, it should be without load. This however, seldom happens in practice, as there are many C. O. D. packages in each delivery that must be returned to the store as collection could not be made. Also packages sent out on approval are called for and brought back to the store on each trip. Hence, as a general thing, the load does not entirely disappear before the wagon reaches the store at the end of any one delivery. It may be safely assumed however, that the average load carried throughout any trip will not be more than 500 lbs. The load having been received, the wagon starts out to deliver its packages.

The following table gives for a certain store, the division of the city into what may be called unit districts, each store having of course, its own particular scheme of subdivision—this depending upon the volume of its business.

TABLE I.

1	Canal St.,	to Battery,	East and West	2	deliveries a day.
2	" "	" 19th St.,	East of Fifth Avenue	3	" "
3	" "	" 19th "	West of " "	3	" "
4	20th "	" 40th "	" " " "	3	" "
5	41st "	" 59th "	" " " "	3	" "
6	60th "	" 75th "	" " " "	3	" "
7	76th "	" 90th "	" " " "	3	" "
8	91st "	" 105th "	" " " "	2	" "
9	106th "	" 125th "	" " " "	2	" "
10	126th "	" 145th "	" " " "	2	" "
11	20th "	" 50th "	East " "	3	" "
12	51st "	" 80th "	" " " "	2	" "
13	81st "	" 110th "	" " " "	2	" "
14	111th "	" 145th "	" " " "	2	" "
15	All above 145th St.,	East and West		1	" "

It will be observed that on the longer trips only two deliveries are made a day, while above 145th street only one delivery is made. This latter is an all day route and the horse that goes up one day comes back the next—horses being changed at the local stable of this particular store near 180th street.

Let us suppose that the wagon has started on trip No. 7, then it will go from that store to 76th street without stopping, the first delivery being made in 76th street. To make it easier for the horse and to facilitate the delivery, the driver does what is called "backloading." This means giving a number of packages to his helper or delivery boy to distribute on foot, while he drives to another street, makes some deliveries and meets his boy again at some pre-arranged point. By this method the horse is saved a great deal of work and the time of delivery is much shortened. After the deliveries are all made on the way up, for example, between 8th Ave. and Amsterdam Ave. as far as 90th street—the end of this route—then the wagon comes down delivering between Amsterdam avenue and Riverside Drive to 76th street. At this point deliveries stop, and the wagon proceeds to the store, there to deposit the money collected on C. O. D. packages and to return undelivered goods. By this time it is usually after 12 o'clock and the wagon goes to the stable to change horses and prepare for its second trip. The horse used on the morning trip is sent to his stall and a fresh one is harnessed to the wagon. The wagon starts out again at 1 o'clock to load up for another delivery. The same procedure as before is carried out, the wagon usually returning to the stable a few minutes before 5 o'clock. The horse used during the morning trip is harnessed to the wagon again and starts out on the 5 o'clock delivery. This horse returns about 7.30 or 8 o'clock. Hence we

see that it takes two horses for every delivery wagon—the horse that makes only one trip on any one day, making two trips on the following day, on a route calling for three deliveries each day. On a route having two deliveries a day, each horse makes but one trip a day.

It has been found that the mileage per wagon per day is nearly a constant, irrespective of the number of trips made. The method pursued which led up to this conclusion, was the following: An odometer was placed on the axle of a delivery wagon in the service of one of the large department stores in the city. This wagon was sent over each of the routes specified in Table I, an accurate record being kept of the number of miles covered by the wagon on each day. This wagon was kept on the various routes in regular delivery service for a period of some three weeks, and the results obtained indicate that approximately the same number of miles are covered by all the wagons in this service each day. This will be readily understood when one considers that a wagon, making a trip over an apparently short route, is in reality covering very much more ground than would at first be thought. The density of population in the district which the route covers materially affects the number of deliveries and consequently the mileage of the wagon. The explanation of the fact that the average mileage per day of the wagons is nearly the same, is that experience extending over many years of service has taught those in charge the best method of district subdivision which will produce such a proportioning of the work that it shall be equally distributed among the units.

In determining the amount of work done per day by one of these delivery horses, it is essential to know the number of miles traveled by the horse, the average draw-bar pull of the wagon, and the average speed of the horse while in motion. To determine these factors one of the authors spent a number of days on his bicycle, following delivery wagons of many firms, under varying conditions of load and in many different streets. Attached to the bicycle ridden, was an accurately tested cyclometer and an equally accurately tested tachometer. A notebook, pencil and watch completed the outfit, and the following is an illustration of the method pursued in determining the amount of work done by horses attached to delivery wagons in New York city.

The draw-bar pull of the wagon was determined by the use of

a traction dynamometer. For the wagons under consideration it was found that the average pull per ton was 60 lbs. on ordinary cobblestones at a speed of seven miles per hour. On asphalt the draw-bar pull was found to be 40 lbs. per ton at 7 miles per hour. The unit under consideration was composed of a wagon weighing 1300 lbs. drawn by a horse weighing 1100 lbs. Each wagon is provided with a driver and a delivery boy. The average weight of the driver may be taken at 150 lbs. and that of the boy at 125 lbs.. Hence the total weight of the unit without load was 2675 lbs. To this must be added the average load which may be considered as being 500 lbs. Adding this to 2675 lbs. we have as the total weight of the unit 3175 lbs. The weight causing the draw-bar pull however is 2075 lbs. The test recorded below was approximately one-half on cobblestones and one-half on asphalt. The true average draw-bar pull may then be taken as having been 50 lbs. per ton during the test.

The results given in the following table may be considered as showing relatively the average amount of work done by a horse in harness during about 4½ hours in delivery service.

From the above data we find that, starting from the store, the average speed while in motion was 6.7 miles per hour. The actual running time was 1 hour 36 minutes; time at rest 2 hours 28 minutes.

From the time the horse left the stable until he returned to it was 4 hours and 52 minutes. The time taken to load at store was 46 minutes. The time to run from stable to store was 2 minutes. Hence the actual time the horse was working from the time he left the stable until he returned to it was 1 hour and 38 minutes; time at rest 3 hours and 14 minutes.

It will be noticed that the horse was at rest and doing no work for nearly two-thirds of the time.

Taking the draw-bar pull as found, at 50 lbs. per ton, the number of foot pounds of work done by the horse in traveling 11 miles was $50 \times 58{,}080 = 2{,}904{,}000$ foot pounds, or at the rate of 1,781,596 foot pounds per hour, which is at the rate of 29,693 foot pounds per minute. This delivery horse then exerted nearly .9 of a theoretical H. P. for 1 hour and 38 minutes. This was all the work done by this particular horse on this day. The following day this same horse made two trips over the same

TABLE II.

Tabulated Statement of Test.

The weight of wagon	1300 lbs.
" " driver	150 "
" " boy	130 "
" " extra boy	120 "
" " average load	330 "
Total weight causing draw-bar pull	2,050 "
Draw bar pull	50 "

In the following S = started; m = in motion.
R = stopped; r = at rest.

REMARKS.	Speed in miles per hour	At rest and in motion. Mins.	r or m.	Hrs.	Mins.	Secs.	Distance in miles.
Left Stable				1	0	0	0
Arrived at Store	6	2	m	1	2	0	.09
Left Store		46	r	1	48	0	
Stopped at 6th St. to deliver special delivery package	7	23	m	2	11	0	2.67
Started	9	1½	r	2	12	30	
Regular delivery begins here.							
R	9	2½	m	2	15	0	3.045
S		4	r	2	19	0	
R	5.4	2	m	2	21	0	3.32
S		½	r	2	21	30	
R	10.8	½	m	2	22	0	3.32
S		14½	r	2	36	30	
R	4.8	2	m	2	38	30	5.48
S		6½	r	2	45	0	
R	6.42	2	m	2	47	0	3.691
S		4	r	2	51	0	
R	9.6	1	m	2	52	0	3.855
S		4½	r	2	56	30	
R	5.1	1½	m	2	58	30	3.985
S		25	r	3	23	0	
R	6.42	2	m	3	25	0	4.2
S		1	r	3	26	0	
R	5.7	1	m	3	27	0	4.295
S		3	r	3	30	0	
R	6.48	4½	m	3	34	30	4.76
S		15½	r	3	50	0	
R	5.4	3½	m	3	53	30	5.49
S		7½	r	4	01	0	
R	6.6	1	m	4	02	0	5.9
S		1	r	4	03	0	
R	7.5	1	m	4	04	0	5.325
S		4	r	4	08	0	
R	6.24	2	m	4	10	0	5.53
S		1	r	4	11	0	
R	1.2	½	m	4	11	30	5.54
S		½	r	4	12	0	
R	9.6	1	m	4	13	0	5.7
S		8	r	4	21	0	
R	7.2	1	m	4	22	0	5.82
S		6½	r	4	28½	30	
R	6.9	2	m	4	30	30	6.05
S		1½	r	4	32	0	
R	4.8	2	m	4	34	0	6.21
S		8	r	4	42	0	
R	7.2	5	m	4	47	0	6.81
S		1	r	4	48	0	
R	6.3	2	m	4	50	0	7.02
S		21	r	5	11	0	
R	7.68	2½	m	5	13	30	7.34
S		1	r	5	14	30	
R	5.4	1½	m	5	16	0	7.46
S		1	r	5	17	0	
R	6	½	m	5	17	30	7.41
S		1	r	5	18	30	
R	10.2	1	m	5	19	30	7.68
S		1	r	5	20	30	
R	7.2	1½	m	5	22	0	7.86
Delivery over, started for stable		1	r	5	23	0	
Special stop at 28th St. & 7th Av.	7.74	20	m	5	43	0	10.25
		4	r	5	47	0	
Stable	7.5	5	m	5	52	0	10.86

ground. From this data the average work done per day the year round by a horse in this class of service, may be taken to be not over 16.5 miles at 50 lbs. per ton, at a speed of 7 miles per hour. Other data bears out this conclusion. It is quite probable that on some special occasion a horse may be called upon to do more than is shown above, but the average work, day by day, for the year is not more than this. In fact experience has shown that a horse in delivery service in New York city cannot average over fifteen miles a day for six days a week and be expected to render good service for any reasonable length of time.

The length of the working life of a horse in this service, is seldom over five years. At the end of this time he has depreciated in value at least 50% and cannot be sold for more than half his original cost.

The time that a horse is in harness per day the year round, will not average more than seven hours, and we have seen that he is only working a small fraction of this time. However, for the purposes of this paper, it will be considered that a horse can do a greater amount of work, day in and day out the year round, than experience has indicated that he accomplishes.

We will assume, therefore that it is possible for a horse to do 21 miles a day under a draw-bar pull of 50 lbs., at seven miles per hour and be in harness eight hours a working day, the year round.

The number of foot-pounds of work done per day by a horse, under this supposition, would be 5,280,000. This is at the rate of 29,333 foot-pounds per minute, or the horse is working at the rate of .89 of a theoretical H. P. for three hours per day. This of course, refers only to the time in actual motion.

Having established the amount of work that a horse is to do per day, it is now necessary to ascertain how much it costs to do this work. The basis upon which this calculation can most readily be made, for comparison with other values, is the ton-mile; that is, how much it costs to transport a ton one mile over a level road under ordinary conditions; the ton weight to include everything that enters as a factor in causing the draw-bar pull of the wagon. These factors are, the weight of the wagon, weight of driver and boy, and weight of load carried. In order to facilitate the calculation, the data collected has been condensed into a table and is given below. This table represents the results of a personal canvass of a large number of stables for

delivery and for general livery service. The figures given are the lowest that were procurable in New York City.

TABLE III.

TABLE OF ITEMS ENTERING INTO THE CALCULATION OF THE COST OF MOVING A TON A DISTANCE OF A MILE ON LEVEL GROUND, IN LIGHT DELIVERY SERVICE IN NEW YORK CITY.

1.	Cost of food per day for one horse	32.00 cts.
2.	Interest on cost of wagon (at 6% per annum) per day, original cost of wagon, $312	5.13
3.	Interest on cost of horse (at 6% per annum) per day, original cost of horse, $125	2.06
4.	Interest on cost of harness (at 6% per annum) per day, original cost of harness, $55	.90
5.	Part of stable rent charged to each horse per day, (Cost of stable, $40,000. Int. at 6% = $2400.) 46 horses in stable, part of rent chargeable to horses = $1578.55.	9.39
6.	Part of stable rent chargeable to each wagon per day, 24 wagons in stable. Part of rent chargeable to wagons = $822.85.	9.39
7.	Part of cost of attendance chargeable to each horse. 4 men to take charge of 46 horses at $11 a week per man—$44. a week for care of horses.	13.66
8.	Shoeing per horse per day ($2. per month a head, the year round.)	6.60
9.	Driver per wagon per day, $12 per week	171.42
10.	Boy helper, $8. per week	114.28
	Total cost of 1 wagon, 1 horse and attendance per day	364.83c.

It is to be understood that this table represents the actual cost per day, to a stable in the city, for a wagon and horse, the figures given being those of a stable connected with one of the large dry-goods houses in the city.

Assuming 500 pounds as the average load carried by any one wagon per day, the total weight of the unit which causes the draw-bar pull as found before, is

Wagon	1800 lbs.
Driver	150 "
Boy	125 "
Load	500 "
Total	2075 "

Hence, draw-bar pull being taken as 50 lbs., the cost to move 1 ton 21 miles may be taken as 364.83 cents, the cost per ton-mile being then 17.373 cents.

Taking another case where the two horses and the delivery wagon are considered, and assuming the most ideal conditions, we find the following:

TABLE IV.

Supposition:

One wagon making three deliveries a day of 800 lbs. each—assuming 500 lbs. average load as before, making a total delivery per day—2400 lbs.

To do this will require 2 horses, 1 wagon, 1 driver and 1 boy. The cost per day of this outfit from Table III is as follows:

1.	Food for 2 horses	64.00 Cts.
2.	Interest on cost of 2 horses	4.12
3.	" " " " wagon	5.13
4.	" " " " 1 set of harness	.90
5.	Stable rent chargeable to 2 horses	18.78
6.	" " " " wagon	9.39
7.	Attendance on 2 horses	27.32
8.	Shoeing for 2 horses	13.20
9.	Driver	171.42
10.	Boy	114.28
	Total	428.54 Cts.

The cost of delivery per pound is then .17856 cents. If we assume that in doing this work the wagon was out 12 hours and is in motion one-half its time, going at a speed of 7 miles per hour while in motion, then the wagon will cover 42 miles per day. Under these conditions the cost per ton-mile is 10.2 cents. This is also the cost per car mile in this case.

If we consider the load only, it costs 10.2 cents. per 500 lbs. per mile, or at the rate of .0204 cents per lb. per mile.

If we assume that on the three trips the deliveries average 50 per trip, then 150 deliveries were made per day. This is at the rate of 25 deliveries an hour or 1 delivery in 2.4 minutes. It is well to call attention here to the fact that a wagon sometimes is called upon to make as high as 100 to 150 deliveries on a single trip and the average rate of delivery may be taken as not over 25 deliveries an hour. Hence it is evident that the case considered in Table IV. is for ideal conditions only. The weight per package under our supposition is 16 lbs. and it is not often that the packages will average over 10 lbs.

The results deduced from Table IV. it will be understood, represent the lowest possible figure under the conditions now existing in the stable under consideration. Therefore, if, in making a comparison between the cost of operating a horse and an electric delivery service under identical conditions, the above figures

are used, all possibility of error in favor of the electric automobile would seem to be eliminated.

SECTION II.

Some Tests on Electric Automobiles for Delivery Service.

The results recorded in this section were obtained under service conditions, in the streets of New York city. Over 60 miles were covered during the tests recorded below, and all grades between the lower section of the city and Washington Heights were surmounted with the greatest ease. During the tests, various conditions of weather were encountered, including heavy rain, strong head winds and muddy streets, as well as very clear weather, no wind, and dry streets.

During the series of tests, no accidents of any kind happened. It was not necessary at any time to stop the vehicles for repairs—all the mechanical and electrical parts performing their functions with the utmost ease, and with practically no noise, and absolutely no odor.

The method followed during all the tests was the same. It consisted in measuring the watt-hours of energy supplied by the storage batteries during the runs, by means of a Thomson recording watt-hour meter, which was accurately calibrated before the test began. The distance traveled by the vehicles was recorded by a tested cyclometer and the speed in miles per hour was noted at any second by means of a tachometer. Placed in series with the watt-hour-meter, was a Weston portable ammeter, while a Weston voltmeter was placed across the battery connections at the controller. In this way, instantaneous readings of the power were obtained, while the watt-hour meter gave the total energy used. The Weston instruments were accurate, and every precaution was taken to guard them from any jolts or jars which might have impaired their accuracy.

The first tests to be presented were made upon a vehicle built for a large dry-goods store in New York city. The vehicle was intended for the delivery of light goods about the city, and was to be placed in competition with horse delivery service of the same class. The results tabulated below, show the instantaneous power consumption with this vehicle, while traveling over the same ground, at the same speed as recorded on two different days. The column headed "rain" refers to readings taken during a severe storm which lasted throughout the entire test.

The column headed "clear" shows the consumption of power on a clear day with no perceptible wind.

TABLE V.

LOCATION OF VEHICLE AT TIME OF READING.	Speed in miles per hour.	Voltmeter Reading.		Ammeter Reading.	
		Rain.	Clear.	Rain.	Clear.
Going North.					
5th Ave. & 19th St	10	87	86	24	24
5th Ave. & 35th St., 4 per cent. grade	7	84	83	44	42
5th Ave. & 38th St.	10	86	85	25	25
Passing Cathedral, 50th St. & 5th Ave.	10	86	85	26	27
59th St., passing N. Y. A. C.	10	86	85	25	25
59th St., East end of Spanish flats, 3 per cent. grade	8	85	84	35	35
61st St. & Boulevard	10	86	85	21	21
76th St. & Boulevard	10	86	85	24	24
104th St. & Boulevard	9	85	84	30	30
Going South.					
119th St. & Boulevard, N. cor. of Barnard, macadam 4 per cent grade	5	80	81	47	44
106th St. & Boulevard	10	84.5	84	22	20
92nd St. & Boulevard, 3 per cent grade	6	83	82	31	32
82nd St. & Boulevard, down grade	12	85	84	17	16.5
Madison Av. bet. 24th & 25th St., No. 3 speed.	10	83	82	23	22
No. 2 speed	5	43	42	19	21
No. 1 speed	2	22	21	19	22
9th Ave., bet. 19th & 20th St., cobble stones, No. 2 speed	5	42	42	21.5	22

An inspection of Table V. brings us to the conclusion that the power consumption is not greatly affected by change of pavement, as from cobble stones to asphalt. There is, however, a slightly greater power required on wet macadam than on dry, and more power is required on macadam than on asphalt or cobbles. The grades were measured in every case after the tests were completed. In Table VI is given the data obtained during a test run of a little over 13 miles, in very bad weather. For the greater part of the trip, a heavy wind was blowing.

The time given in the last column of this table has no bearing on the speed. The speed may have been 10 miles an hour while running and yet, owing to "slow-ups," stops, etc., the time occupied in passing from one street to another where the readings of the time were noted, may indicate a speed of only 6 miles an hour. The last column was inserted as a check on the trip—the speed in the second column being given as the speed at the time the readings of the voltmeter and ammeter were taken, the watt-hour-meter, of course, taking care of the intermediate fluctuations.

TABLE VI.

LOCATION OF VEHICLE AT TIME OF READING.	Speed in miles per hour.	Voltmeter Reading.	Ammeter Reading.	Time.	
				Hrs.	Mins.
Going North					
110th St. bet. 5th & 6th Ave.	9.5	85	28.5	3	13
110th " " " "	9.5	86	27	3	14
5th Ave. & 21st St.	10	87	24	3	16
Down grade.	10	91	0	3	18
5th Ave. passing Astoria 2½ per cent. grade.	8.5	85	34.5	3	20
34th St. & 5th Ave., 3 per cent. grade.	7	85	37.5	3	21
36th St. & 5th Ave., 4 per cent grade.	6.5	84.5	41	3	23
39th St. & 5th Ave.	10	86.5	22		
43rd St. & 5th Ave., down grade.	12	87	19	3	25
57th St. & 5th Ave., down grade.	13	87	18	3	31
59th St. & 6th Ave.	10	86	25.5	3	32
59th St. & 8th Ave.	11	86.5	21	3	35
Passing 22d Regt. Armory on Boulevard.	10	86	23.5	3	40
79th St. & Boulevard, down grade	14	86.5	17		
93rd " " "	15	87	16		
110th St. & Boulevard	10	84.5	25	3	53
119th " " down grade.		8,.5	0	3	54
Stopped here 18 minutes.					
Macadam.					
126th St. & Boulevard, going north, 4 per cent. grade.	4	81.5	47.5		
127th St. & Boulevard, 4 per cent. grade	4	82	47	4	18
Passing Manhattan College, 134th St. & Boulevard, 4 per cent. grade.	4	81	52		
135th St. & Boulevard, 4 per cent. grade.	4	81	47.5		
Going South.					
125th St. & Boulevard, 4½ per cent. grade.	3	80	56	4	25
124th " " " " "	3	80	56	4	26
122nd " " 4 " "	3	80.5	51	4	27
122nd " " " "	3	80	50	4	28
Asphalt.					
118th St. & Boulevard, 3½ per cent grade.	4.5	81	42		
108th " " down grade.	14	85	16	4	34
100th " " " "	15	84	13		
96th " " 1 per cent. grade.	9	84	26		
94th " " 3 " "	6	83	33	4	37
88th " " down grade.	13	84	15.5	4	40
69th " " "	12	84 5	20	4	46
65th " " "	10	84	23		
50th St. & 8th Ave.		88.5	0	4	54
26th St.—going East from 8th Ave.	9.5	83	28	5	04
23rd St., bet. Madison Ave. & Broadway, cobble stones, slightly up grade.	9	82	33		
2c th St., bet. 5th & 6th Aves.	10	83	21	5	13
At end of run.		88	0		

A study of Table VI, shows us that on grades the speed of the vehicle is very much reduced and that the power required to propel the vehicle at the reduced speed is very large—which is quite natural. The table is instructive in showing the relative proportion of increase of power due to grades. It must be remembered, however, that the comparison is made in this case between level asphalted streets and macadamized hills that were very muddy, and that this condition would cause the variation in power to be greater than in the case of grades of asphalt surface. The average of ten readings taken from Table VI, gives the power consumed on level asphalt as follows:

Volts..... 85.8
Amperes..... 23.1

It is to be understood that these ten readings were selected from the table with the idea of eliminating up or down grades. The lowest ammeter reading taken was 20 and the highest 26. Above and below these readings the vehicle was on perceptibly up or down grades. It may be well to note that this wagon was equipped with solid rubber tires; these, as is quite generally recognized, absorb slightly less power than pneumatic tires.

Table VII gives the results obtained during a test in very fine weather. The run was one of 6.25 miles over a continually ascending route.

TABLE VII.

The voltage of the battery on open circuit before the start was 91. This is equivalent to 2.09 volts per cell.

LOCATION OF VEHICLE AT TIME OF READING.	Speed in miles per hour	Voltmeter Reading.	Ammeter Reading.	Time.		
				Hrs	Min.	Sec
Started from 219 W. 19th St.				3	11	15
19th St. bet. 7th & 6th Aves.	10	86	24			
19th St. bet. 6th & 5th Aves.	10	86	25			
23rd St. & 5th Ave.		90	0			
Stopped 30 seconds here.						
27th St. & 5th Ave.	10	85	25	3	18	36
30th St. & 5th Ave.	10	85	24	3	19	40
32nd St. & 5th Ave.	9	85	32	3	20	20
Passing Astoria stopped 10 seconds.						
36th St. & 5th Ave.	8	84	33	3	23	15
42nd St. & 5th Ave.		90	0			
Stopped 20 seconds here.						
49th St. & 5th Ave.	10	85	28	3	30	30
59th St. opp. Plaza Hotel.	10	85	28	3	34	15
60th St. & Boulevard.	10	85	25	3	37	10
66th " "	10	85	25			
67th " "	10	85	25			
68th " "	10	85	24	3	41	39
69th " "	10	85	24			
70th " "	10	85	22	3	42	0
72nd " "	10	85	22	3	43	10
75th " "	10	85	25	3	44	10
82nd " "	10	85	22	3	46	10
83rd " "	10		25	3	46	27
86th " "	10	85	25	3	47	27
87th " "	10	85	28	3	47	58
88th " "	10	84.5	28	3	48	20
91nd " "	10	84	28	3	49	55
Down grade.		89	0			
99th St. & Boulevard	10	84	28	3	51	55
101st " "		84	28	3	52	38
106th St. stopped to take picture, at rest 5 minutes 10 seconds.						
112th St. & Boulevard.	9	83	31			
114th " "	10	84	22	4	6	50
S. end Eng. Bldg. Col. Univ.	10	83	27	4	9	29
120th St. & Boulevard.		88.5	0	4	10	15

The watt-hour meter reading during this test showed a consumption of 1364.22 watt-hours. The wagon alone was weighed on balanced coal-scales and was found to weigh 3750 lbs. On

this trip it carried three passengers and the instruments used. The total weight was found to be as follows:

Weight of wagon	3,750 lbs.
" " passengers	413 "
" " instruments	37 "
Total weight	4,200 "

The distance travelled was 6.25 miles and the time actually in motion was 52.75 minutes.

Therefore;

Average speed in miles per hour was	8.44 miles.
The watt-hours per car mile were	218.28
The watt-hours per ton mile were	103.95

It should be remembered that these results were obtained during a run which was always tending up hill as was noted above. This becomes quite evident when the average of the 27 readings of Table VII is compared with the average of the 10 readings taken from Table VI, representing level asphalt.

Average of the 27 readings of Table VII.

Volts	84.72
Amperes	26.25

Average of the 10 readings taken from Table VI.

Volts	85.3
Amperes	28.1

TABLE VIII.

LOCATION OF VEHICLE AT TIME OF READING.	Speed in miles per hour	Voltmeter Reading.	Ammeter Reading.	Time. Hrs.	Min	Sec.
Started from 120th St. & Boulevard.				4	23	10
Voltage on open circuit		89.5				
Going South.						
118th St. & Boulevard, macadam, 3½ per cent. grade		81	40			
S. end. Eng. Bldg. Col. Univ.	10	84	25	4	24	20
77th St. & Boulevard	10	83	23	4	31	15
72nd " "	11	84	20	4	35	30
70th " "	10	82	25	4	37	30
Passing 22nd Regt. Armory	12	81	18	4	38	20
Passing Empire Hotel.	10	82	23	4	40	30
59th St. bet. 7th & 8th Aves.	10	82	25	4	43	15
Passing Spanish flats, down grade.	11	87.7	0			
Passing N. Y. A. C.	9.5	82	25	4	45	0
56th St. & 5th Ave.	9.5	81	27	4	47	0
53rd St. & 5th Ave.	9.5	81	29			
Stopped 10 seconds here.						
30th St. & 5th Ave.		82	22	4	56	30
Ran through 26th St. to make special tests, stopped one minute here.						
5th Ave. & 24th St.	9	81	22	5	15	0
19th St. bet. 5th & 6th Ave.	9	82	20	5	19	50
End of run.		87	0	5	21	45

Table VIII. gives the results of a run made in the opposite direction to that recorded in Table VII., that is starting on the

high ground on which the run of Table VII. terminated; it records the power consumed during a run of 7.24 miles. The run ended where that of Table VII. began. Thus in the run recorded in Table VIII. the tendency was always down hill; this will be appreciated from an inspection of the table.

The watt-hour-meter showed a consumption of energy on this run of 1243.38 watt-hours. The weight was the same as previously given, namely 4,200 lbs. The time in actual motion was 58.5 mins. The distance travelled was 7.24 miles. The average speed per hour 8.08 miles.

The watt hours per car mile were 171.74
The watt-hours per ton mile were 81.08

Combining the results of the watt-meter readings for the tests of Table VII and VIII, we find that for a total distance of 13.49 miles the average was as follows:

Watt-hours per car mile 195.01
Watt-hours per ton mile 92.875

The results were obtained under the ordinary service conditions and can be duplicated at any time.

To determine as accurately as possible the lowest value for the power consumption at the different speeds, some special tests were made. A block paved with asphalt which was fairly level between 24th and 25th streets, on Madison Avenue, was selected for the tests. The method of procedure was as follows: First, readings were taken while the vehicle was passing between 24th and 25th streets and then readings were taken when passing back over the same ground, in every case care being taken that the vehicle had reached a constant speed an appreciable time before the readings were noted. The average of these readings should, of course, eliminate any slight grades, if present, and the average should give the true power consumption for absolutely level asphalt. The readings obtained for the three different speeds of the wagon were:

	Volts.	Amperes.
No. 3 speed—10.5 miles per hour	82	22
	82	20
Average	82	21
No. 2 speed—5.4 miles per hour	42	21
	42	18
Average	42	19.5
No. 1 speed—2 miles per hour	21	22
	21	16
Average	21	19

At No. 3 speed the rate of travel was 15.4 ft. per second and the rate of work 1722 watts. Since a watt represents 0.7373 foot pounds per second the total work required to propel the vehicle at this speed for one second was 1269.63 foot pounds. This represents a rate of 2.3 H. P. The draw-bar pull was then 52.44 lbs. or at the rate of 39.26 lbs. per ton. At No. 2 speed the draw-bar pull was 36.3 lbs. per ton. The value of the draw-bar pull at No. 3 speed is probably very closely approximate to the value that would be shown at all speeds between 5 and 12 miles per hour if a dynamometer were used. From the results recorded in Table VII. we may take 105 watt-hours per ton mile as quite within the reach of actual practice under service conditions to-day. However, a more conservative estimate of 120-watt-hours per ton mile as a basis upon which to calculate the operating costs of electric vehicles for delivery service will be assumed. Under ordinary conditions a well-designed electric delivery wagon should not consume over 120 watt-hours per ton mile. In support of this statement the following data is presented, these results being obtained while testing a small carriage which, owing to a number of circumstances, had failed to come up to the expectations of the designers. This carriage had been sent back to the shop for some alterations and it was at that time that an opportunity was afforded for making a number of experiments and tests upon it. The point of greatest interest in these tests is the fact that though working under most unfavorable conditions, the watt-hours per ton mile did not reach 120. The weight of this vehicle was 1200 lbs., over 300 lbs. more than the original design called for. With one passenger and the instruments it weighed 1400 lbs. Its draw-bar pull was found, by a dynamometer, to be over 42 lbs. at 8 miles per hour on level asphalt. This is at the rate of 62 lbs. per ton, and is approximately the same as found for ordinary horse delivery wagons on cobble stones. This excessive draw-bar pull was due to poor bearing design. Table IX gives the result of a run of 9.45 miles with this vehicle on New York city streets.

TABLE IX.

Distance traveled	9.45 miles.
Watt-hour meter record	771.15 watt-hours.
Average speed	8.0 miles per hour.
Watt-hours per ton mile	116.5

It is interesting to note that even with this abnormal pull the watt-hours per ton mile were only 116.5.

The test recorded in Table X was a fairly severe one so far as hill climbing and bad roads are concerned. The vehicle on this occasion traveled from 59th street up the Boulevard to 137th street and return, taking en route the long hill from 125th street to 137th street on the Boulevard; on the return the hill from 125th street to 117th street was surmounted. The hill-climbing part of the trip was over a very bad macadam road surface. The hill at 96th street and the Boulevard was surmounted twice during the trip and the carriage covered a distance of 14 miles.

TABLE X.

Distance traveled	14 miles.
Time in actual motion	1 hour 47 minutes.
Average speed	7.8 miles per hour.
Total watt-hours recorded	1162.29
Watt-hours per ton mile	118.57

It is worthy of note that with all the hill climbing, the bad roads and the large friction loss due to bad design, the watt-hours per ton mile reached only 118.57. From the above, 120 watt-hours per ton mile would seem to be a conservative estimate for the power consumption of well-designed electric delivery wagons in New York city under ordinary service conditions.

SECTION III.

Horse versus Electric Delivery Service.—A Comparison.

In considering the advantages and disadvantages of two radically different systems for the performance of the same work, the cost is the deciding factor, if other things are equal. Assuming that all other considerations are equal, it will be shown in this section that the cost of operation, maintenance, etc., of the electric automobile is less than for horses in the light delivery service of New York city, the horse being considered in the most favorable light.

From the results recorded in Section II. we are led to the conclusion that, under highly disadvantageous conditions, the power necessary to propel a vehicle through the streets of New York city from the lower part of the town to points situated on the highest ground, including all grades that may be encountered, will not average more than 120 watt-hours per ton mile. That this is a high figure for vehicles of good design and equipment is evident from the results obtained while testing the delivery

wagon previously mentioned. The fact that the small carriage never reached 120 watt-hours per ton mile, though working under most unfavorable conditions, should lend weight to this conclusion.

Taking 120 watt-hours per ton mile as a basis from which to compute the power consumed by an electric delivery wagon, we will now compare the results obtained in Section 1., Table IV., with the results that would be obtained if an electric wagon were substituted.

From Table IV it was found that the total cost per day for 2 horses, 1 driver and 1 boy, was 428.54c. The wagon was to travel 42 miles a day—being an average of 21 miles per day for each horse. The time in motion was assumed to be 6 hours. An electric wagon with an average speed of 9 miles an hour, could cover this distance in 4.66 hours, thus saving 1.34 hours—the other conditions remaining the same. The cost per day for the electric, assuming cost of power at 5c. per K. W. hour, is given in Table XIII.

TABLE XIII.

1. Cost of power for 42 mile run, at 5c. per K. W. hour..... 71.28c.
assuming power consumption as 120 watt-hours per ton mile.

Weight of wagon.....	3750 lbs.
" " driver.....	150 "
" " boy.....	125 "
Average load.....	500 "
Total weight.....	4525 "
	2.263 tons.

Watt-hours per car mile, 271.56
" " " 42 " " 11,405.00 = 11.405 K. W. hours.
Taking battery efficiency as 80%.
Total power to be paid for = 14.256 K. W. hours.

2. Interest on cost of wagon per day..... 37.89
Cost of wagon, $2,300. at 6% interest.
3. Interest on stable rent for one wagon 9.39
4. Driver..... 171.42
5. Boy..... 114.28

Total cost per day for 42 miles, 1 wagon, 1 driver and 1 boy 404.26c.

Therefore, cost per pound of delivery is .16844c., or .01012c. less than the figures for the horse. The cost per car mile is 9.625c. or .575c. less than for the horse. Cost per ton mile is 4.25c., or 5.95c. less than for the horse service. If we consider the load only, it costs 9.625c. per 500 lbs. per mile, or at the rate

of .01923c. per lb. per mile or, .00115c. less per lb. than for the horse service.

Attention is again called to the conditions under which this comparison is made. The horse is supposed to be able to average 21 miles per day, doing this at the rate of seven miles per hour, under a draw-bar pull of 50 lbs. In other words, he is doing work at the rate of .89 of a theoretical H. P. for three hours per day. The automobile, on the other hand, is to do 42 miles a day at the rate of nine miles per hour, and the cost of power is assumed to be 5 cents per K. W. hour. Under these conditions the automobile can do the work of two horses in 1.34 hours less time than they can do it in and with a saving of .01012 cents per lb. of goods delivered or at a saving of 24.288 cents per day on a delivery of 2400 lbs.

Now having shown that it is cheaper to use an electric delivery wagon than the present horse delivery wagon—even when the supposition is made that the horse is doing much more work than he really is—it is proposed to make a comparison between the two systems under conditions which actually exist to-day. It was shown in Section IV. that the delivery horse does not average 18 miles per day during the year. We will assume, however, that the horse does travel this distance per day. Each wagon will go 36 miles a day under this assumption; hence the total mileage of the wagon for the year will 11,268 miles. This assumes that on Sundays the wagon does not go out. Then for 52 days a year, at least, the horses have to be fed without any work in return. This, of course, is a condition not met in electric automobile service.

The cost per day for the two horses, wagon, driver, etc., necessary to accomplish 36 miles a day was found from Table IV., Section I., to be 428.54 cents. The cost of covering 11,268 miles will then be $1,562.20. Here it must be remembered that 365 days have to be taken. The cost per car mile is then 13.86 cents.

When we come to consider the electric automobile for a year, covering 36 miles a day, its advantages are brought out very clearly. Since the vehicle, owing to the nature of its construction, does not consume any energy when not in motion, it follows that, during the periods of rest, while deliveries are being made and the wagon is being loaded, there is no more expense than that incidental to wear and tear. This, of course, is common in amount to all vehicles of the same class and may be considered

the same in each case. That a slight loss does occur when the vehicle is at rest, due to local action, etc., in the batteries, is true, but this loss is considered when the efficiency of the battery is taken at 80%. We may say then, that the factor most important in determining the expense of operating an electric vehicle is the price that must be paid for the power. This is a very variable factor indeed and the price per K. W. hour will determine in all cases the amount of saving that will be possible through the use of electric automobiles.

A stable taking power from a large central station would, if of average size, add a load which, if properly distributed as it easily could be, might become a considerable factor in straightening out the load curve of the station. If several stables were supplied from the same central station, this load would become a great source of economy to the station, and power could be sold to them at a very low figure. Owing to the regular nature of the work imposed upon the wagons in delivery service it could easily be arranged to have the electric vehicles charged at night after the heavy load is off the station. They might also charge early in the morning and at noon or at periods that experience would indicate were the most advantageous for the station, the time of deliveries being adjusted to suit the new conditions. In this way a stable should be able to buy power at from 1 to 2 cents per K. W. hour. As this time has not yet arrived we will install for our purposes a small isolated gas engine plant. A plant of this kind should be able to produce a K. W. hour, at the switchboard for 3 cents. Assume the cost for a K. W. hour, as 3 cents, the power consumed per ton mile as 120 watt-hours and the weight as 3,500 lbs., for the wagon. Taking the average load as 500 lbs., weight of driver as 150 lbs., and that of boy as 125, the total weight is 4275 lbs. The cost for the electric vehicle to cover 11,268 miles is given in Table XIV.

TABLE XIV.

1.	Cost of power for 11,268 miles at 3 cents. a K. W. hour, and a consumption of 120 watt-hours per ton mile, total weight = 4,275 lbs., = 2,137 tons, watt-hours per car mile = 356.44, K. W. hours per 11,268 miles = 2889.57, taking efficiency of battery at 80% K. W. hours to be paid for = 3621	$108.35
2.	Interest on cost of wagon at 6% for year. Cost of wagon, $2,300.	138.00
3.	Interest on stable rent for 1 wagon, for year	34.28
4.	Driver	625.68
5.	Boy	416.83
	Total cost per year	$1,323.14

Then the

Cost per car mile	11.74 cents.
" " ton mile	5.49
" of power per mile	.961
" " power per ton mile	.45

Hence the saving considering that the horse drawn wagon does 36 miles a day 6 days a week, is 2.12 cents per car mile in favor of the electric vehicle which means a saving of 76.32 cents per day per wagon.

Owing to the greater speed of the electric vehicle, it takes only 4 hours to travel 36 miles as against 5.14 hours for the horse. This is a saving of 1.14 hours per day, or of 356 hours a year.

The figures given above speak for themselves and would appear to be a most effective argument in favor of adopting the electric automobile for delivery service.

SECTION 4.

Conclusion.

In light delivery service in large cities, when a number of units are employed by individual firms, the adoption of the automobile would seem to be merely a question of time. For this kind of service it seems pre-eminently the best solution. It is cheaper to operate than horse service, and the mechanical problems have been so far solved as to make the vehicles commercially successful. Though, as stated before, it is not the intention to discuss depreciation, it may be noted that the comparison of the costs of operation as regards food, cost of power, etc., would show a saving in favor of the electric delivery wagon, in one year, of 15%, which, under more favorable conditions as to the price of power, might easily be increased. Assuming, for the moment, that the depreciation in a year is 20% for the electric system, and, under the same service conditions, is only 10% for horse traction, we still have a saving of 5% in favor of the automobile. The advantages that will arise from the substitution of mechanical propulsion for horse traction on a large scale, are so well known and understood, that any extended consideration of the subject seems unnecessary. Among the many advantages, however, the following would seem to be the most important.

1. The hygienic condition of large cities will be improved, and the cost of street cleaning will be decreased.

2. The wear and tear on pavements and streets will be reduced, and the use of rubber tires will lessen the noise in the crowded streets.

3. The traffic in cities will not be as congested, owing to the saving in space now occupied by the horse. When we consider that there are approximately 200,000 horses used in New York city alone, and that a horse increases the length of a unit by nine feet, it can be readily appreciated how great a saving will be effected. Taking the average width occupied by a horse and shafts as two feet, it is seen that 200,000 horses occupy about 3,600,000 square feet, or 82.6 acres of valuable street room.

4. When the use of automobiles has become more general, the cost of operation will be reduced. This is true, for the reason that with an increased output of wagons, the price will decrease, and with the greater use of power, the cost of it for this purpose will diminish.

5. The danger of accident from runaways will be eliminated.

A paper presented at the 10th General Meeting of the American Institute of Electrical Engineers, Boston, June 28th, 1889. President Kennelly in the Chair.

ELECTRIC AUTOMOBILES.

BY ELMER A. SPERRY.

At the National Electric Light Association meeting a few days since, Mr. Crosby gave expression to a sentiment which has been rapidly taking form for the past twelve months. He said: "To-day we are as near sweeping the horses off the street with the automobile, as we were in 1889, in taking them off the tracks with the electric car."

Why, I ask, was the date '89 chosen? True, it marks a decade in the history of a branch of electrical application which has made the most stupendous strides; in fact, distanced all sober predictions as to achievement. It marks more. To those associated with the early development of electrical traction, it was about these years that the conservative engineer began to breathe easily; through rigorous experience that seemed nigh about interminable, he became convinced that at last, insulation and materials peculiar to the art, startlingly new to, and even held in derision by, the traction engineer, could nevertheless be relied upon to do the rugged work of heavy traction.

By '89, what we might call a "motor mortality" under severe conditions of service had been reached, that meant success. In a space then considered contracted, we had found room for ample area of journal and commutation; ample insulation and dielectric, to withstand the voltage strains. Methods of supporting and imbedding insulation and conductors had been devised, that ensured life not only against heat and overload, against vibration, pounding and concussion, and last, but not least, against misuse and abuse at the hands of the non-expert.

It had been an evolution, gradual though rapid; many had

contributed to its success; it had finally placed on a firm basis, the dream of the engineering world from the time of Watt, down; namely, "the rotary motor." The achievement can hardly be over-estimated. Unnumbered engineers had planned, toiled and passed with the solution of this enchanted problem almost within their grasp. A rotary motor with no oscillating or reciprocating part had at last been developed. It delivered torque, pure and simple—constant and regular, and had a capacity

Fig. 1.

measured by its size, and an efficiency measured by other motors, nothing short of wonderful. The motor was simply ideal.

At first, much was said to the effect that the machine was not a prime mover; but it had been "hitched to a star." Its system of connection with the prime source of power was at once so complete, and its association so intimate as to perform more acceptably and economically than the prime mover itself, and as compared with the smaller sources, its economy back to the fuel, even at miles distant, was found to be superior.

The fact that the electric motor is a rotary motor, contributes to the success of electric motor-driven systems to a degree diffi-

cult to over-estimate. Our compressed air friends, compelled as they are, to use a multiplicity of reciprocating engines as motor, have made a long step backward and are certainly in the rear in this, as in other features of their system.

The electric automobile coming upon the scene at this time

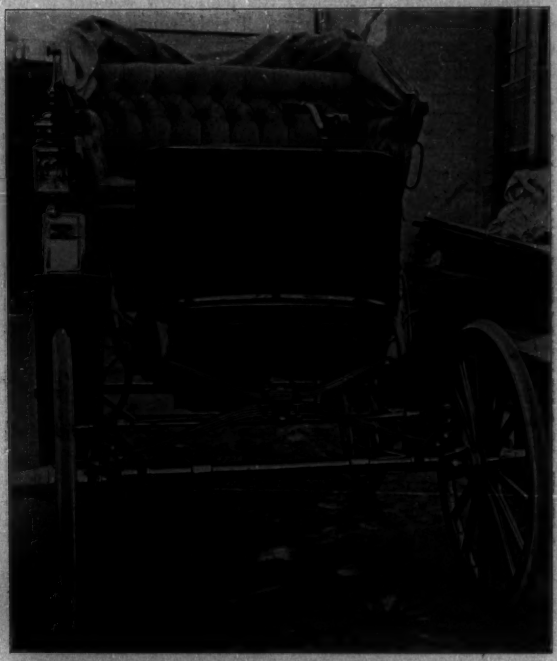

Fig 2.

falls heir to many of the rich results worked out in connection with tramway traction. There are many who go so far as to predict that the younger claimant will displace the former, especially the lighter class of street car service, and this doubtless will be the case to a degree.

Electric railways are rapidly reaching out with wider radii of operation and heavier and heavier equipment, and the automobile

will doubtless have wide use as supplemental to the heavier systems. In fact, co-operation has already been proposed in a number of instances. Its great flexibility and independence of track render it the ideal urban conveyance.

As the perfection of the electric motor gave the first impetus to electric tramway traction, so the point now reached in the perfection of the storage battery will yield equal results in the field of the electric automobile. The past three years have advanced the art remarkably, and drawn to it the attention of both skill and capital, and results have followed.

Fig 3.

The perfected storage battery presents some remarkable features. It even rivals the electric motor in its fitness and special adaptability to the automobile problem. Its very large reserve power at instant command ; its entire freedom from danger when fully charged ; its almost constant pressure throughout its capacity; its recently developed capacity for quick charging ; and ease with which charge may be obtained in almost any hamlet in the country, are among its advantages.

The author can state definitely from personal tests of the principal types of batteries built on the Continent and in England that most of the published records are trustworthy as to specific capacity at the various rates. Some of the structures, however,

are open to serious objection from the standpoint of vehicular traffic. For instance, one of the most popular French batteries, though packed with the utmost care, reached this country with 50% of the positives broken off, and upwards of 40 fragments of positive plate disintegrated, per cell. What are we to expect with such a cell in the hands of the non-expert? Fortunately materials are at hand and systems of developing the plates perfected that render them thoroughly reliable and commercial to a degree commensurate with their life. The recent claim of one maker that batteries light enough for traction purposes would live through 5,000 full discharges is hardly credible, though the negatives of some special types seem to indicate a near approach to this figure. The engineer is at present engaged in increasing the

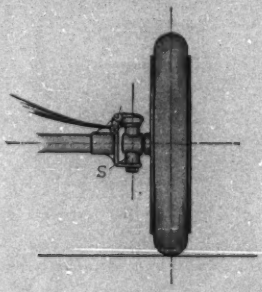

Fig. 4.

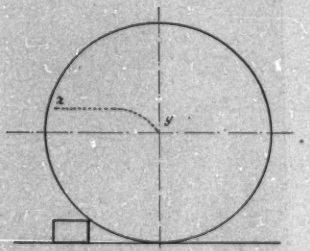

Fig. 5.

life of the light positive, with every indication of success, at least beyond the point ensuring commercial requirement.

It has been supposed that compressed air is the ideal stored power, but it is safe to say that electric storage distances it in the important features. Compressed air reservoirs weigh about 85 pounds per cubic foot capacity for air at 2,000 pounds pressure to the square inch, the air itself weighing nearly 11 pounds. How many horse power hours will this cubic foot develop? Those who know are reticent. It is found that by adding to the air a large quantity of heat, at extra cost, by compounding cylinders and using pressure reducers and wire-drawing valves, all with added weight, that about .27 of a horse power hour may be obtained. We know that this weight of storage battery will develop 1 1-2 horse power hours, requiring no reducing valves

and maintaining its pressure practically at one point until exhausted, rather than gradually exhausting the pressures, as with air. This straight line of discharge of the batteries is not matched by any other storage system of which we now have knowledge.

In common with other systems, the automobile has its limitations which are just beginning to be understood. These are, however, largely those of roadway and materials now employed. The fact that yielding tires are at present (practically) indispens-

Fig. 6.

able, amounts to a tacit acknowledgment of the prevalent inferiority of roadway and pavements. The universal cry of the automobilist is for good roads, and no one improvement will do more to create a giant industry.

Should the pavements ever be so improved as to render the rubber tire unnecessary, would the steel tire do the work? The bearing of this question upon the heavier class of automobile drays, vans, etc., led the author to cause trials to be made touching this subject. Tests were made with a vehicle, having two

driving wheels, supplied with smooth, wide-faced steel tires, 72″ in diameter, carrying 60% of load. The approximate draw-bar pull was ascertained on various kinds of pavement, dirt and gravel roads and macadam, on the level, and on grades, wet and dry. It was found that under the most adverse circumstances, ample adhesion could be relied upon for any conditions liable to be met. Soapy and greasy Belgian block pavement was found to give most trouble, but even here, 20% drawbar pull could easily be relied upon, with some, but not serious, slipping.

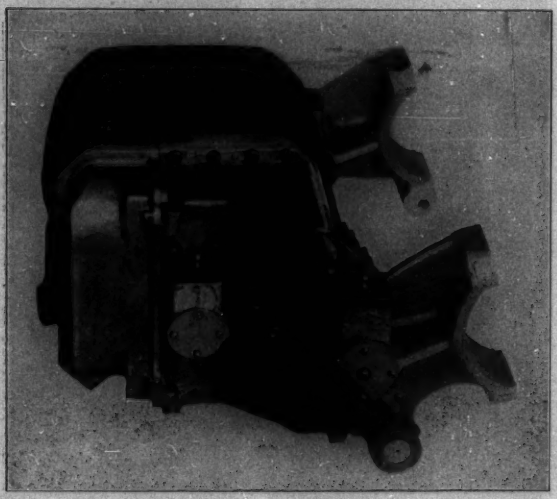

Fig. 7.

A lasting impression of the adhesion and value of smooth tires for road traction, is made by seeing a vehicle of this kind, ascending a 20 per cent. grade on an ordinary gravel road and rising easily, uphill over a 4″ x 4″ timber, placed in front of first one and then both the driving wheels, working as well on the wet portions as on dry.

The designer of the autombile is confronted with some practical problems which have not received attention at the hands of the railway engineer. For instance, in the simple matter of rendering the vehicle directible and easily controlling the guiding

mechanism. Especially is this true in so arranging the parts that obstructions will not easily derange the mechanism or throw the vehicle out of its course. When one or the other of the guiding wheels encounters an obstruction of importance, the reaction works back to the guiding handle, tending to "whip" it out of the hand of the operator and throw the vehicle out of its course. (Recall the threshing of pole or thills in ordinary vehicles.) Many attempts have been made to reduce the leverage of reaction, but at best it has remained a problem of some importance.

Fig. 8.

The accompanying illustrations, Figs. 1 and 2, shows the method employed by the author. Tests designed to thoroughly demonstrate the practical operation of the device, and especially to compare it with the one ordinarily employed are illustrated in Figs. 3, 4, and 5. It was found that the amount of side-thrust transmitted to the guiding handle was practically in proportion to the leverage measured by the distance between the steering axis and the plane of the wheel, *at the height of the point of interception* of the obstruction. A 20″ controlling handle was connected for equal angular movement with the swivelling axles, the wheels

being the same diameter, viz., 32″ and loaded with the same weight, viz., 370 pounds. A small obstruction causes so flat a trajectory curve as to be negligible; this curve is seen at x y (Fig. 5). I have used, as the height of obstruction, the smallest dimension of an ordinary Belgian paving block, lying upon its side, assuming this to be the standard obstruction to be encountered by the various wheels in these tests. Operat-

Fig. 9.

Fig. 10.

ing the two devices each a number of times over this obstruction, at different speeds, a moment of effort upon the handle, tending to swing it laterally, or snatch it out of the grasp of the operator, was found to be in the two cases as follows:

Figure 4, ordinary device; mean value for pull = $10\frac{3}{4}$ lbs.

Figure 2, author's device; mean value for pull = 0 lbs.

This shows an entirely different action under practical operating conditions.

It will be seen from Figs. 2 and 3 that the steering axis is made to intersect the plane of the wheel well up from the bottom or ground line, where obstructions are encountered and where they may be met "head on," and therefore entirely neutralized, as has been demonstrated, giving no tendency to deflection of the wheel in either direction.

It is also found that the arrangement gives the vehicle a quality of self-centering, or running straight-forward, *hands off*.

Fig. 11.

This, as will readily be seen, is a natural result of the obliquity of the steering axes. The wheels, when turned, in the act of guiding, describe a conic section, the lowest point of which is the straight-forward running position. Another peculiar feature is, that in this action, each wheel is entirely independent of the other, throwing no stress either upon the connecting or guiding rods. Another excellent effect is the result upon the tires, the act of steering tending to describe a small arc, rather than the usual twisting of the tires. This can be especially noticed when the vehicle is standing still. Fig. 6 shows the inner wheel turned 45°.

This system of mounting the wheels is found to have peculiar advantages on rough roads and over obstructions, preventing entirely the reaction to the steering handle, giving entire immunity from fear of the controlling handle being suddenly wrested from the grasp of the operator; and on ordinary smooth pavements, instantly assuming the forward position, upon being "given the reins." This feature has been employed upon a number of vehicles both here and abroad, and is well received.

It is found with automobiles that while the best practice in

Fig. 12.

tramway traction can be followed closely in the main, yet the different conditions under which the vehicles operate, weight of motor permissible, height at which the motors are mounted, enormous variation in the rolling friction factor, and other points, allow of departures, which have an important bearing on the motor design and construction. For instance:—With the automobile, only a small motor is allowable. This should be light and yet should deliver all the power necessary in case of emergency. It is found practical to use a motor with a somewhat increased ratio of copper to iron, which should have a high overload capac-

ity, but more than all, it is found that the size and weight of the motor can be greatly reduced, if the gears can be practically compounded. This is especially desirable owing to the enormous variation in the rolling-friction factor.

Obstructions and grades are encountered, never met on tram-tracks and at the same time may be coupled with soft road, which, owing to the weights necessarily present, would render progress impossible, unless an inordinately large motor were at hand. At such times, often if a few feet only can be compassed the journey can be resumed. It is under these and similar con-

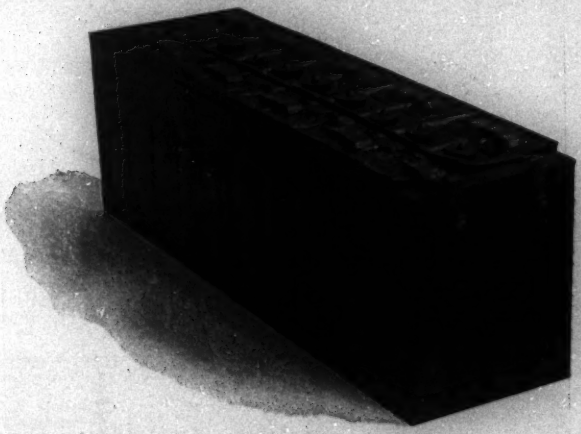

Fig. 13.

ditions, that the value of the compound gear becomes apparent. One form of this gear, employed in a number of vehicles, has been found to be entirely satisfactory, increasing the leverage of the motor over the load. In case of a motor, with a suitable overload factor, this gear, while only doubling the leverage, is found to compass anything that has ever been encountered in city, park and country service. Any ratio of gearing can of course be employed. By means of the compound gear, the torque is brought up to nearly the slipping point of the drivers without overdraft of current-supply from the battery. The manipulation is by a small handle, usually imbedded in the cushion at the side, it being used only at infrequent intervals.

This lever attaches the upright arm seen in Figs. 7 and 8, the gear just being visible. This compound gear not only enables a small motor to meet an emergency, but has an important bearing upon the storage battery, acting as a safe guard in a very important sense, preventing, as it does, inordinate over-drafts of electric current, and in this way, enabling lighter plates to be employed, without fear of "shedding" the active material. Another feature of importance in connection with the compound gear is found to be its interlock and interaction with the controller. This feature renders the compound gear entirely successful in the most incompetent hands. The gear cannot be thrown or changed, when the current is on, nor can the current be put on until the gear is entirely thrown to either one or the other of its normal operative positions. This is done automatically and without the knowledge of the operator.

Speaking again of the motor, as a whole, its elevated position and the comparatively open space it occupies, when compared with street car motors, enables the employment of ventilation. This should be designed with care, so as to prevent ingress of water and moisture. The ventilation is especially applicable to the small sized motor considering the heavy overloads to which they are frequently subjected.

In the hands of the non-expert, simplicity of control is found to be indispensable to satisfactory operation.

With the automobile, there is one handle, which always should be kept in hand, viz., the steering handle. The question naturally arises, "why not let this handle do all of the work of controlling the vehicle?" In a paper before this body, in 1894, the writer pointed out a system of train car control, which has since been widely adopted, in which starting, stopping, speed control and brake were confined to the operation of a single handle. This having now been classed as the best practice with tram cars, why not utilize the combination in connection with the steering handle, allowing it, by the most natural and almost trivial movements, to do the whole work of operation. In this way, the entire control of the vehicle is simplified to a single handle. The direction of the vehicle is controlled by lateral movement of the lever, the vehicle going in any direction to which the handle is pointed or aimed. Depressing the handle, from notch to notch, increases the speed, and pulling up the handle, as one would draw in the reins, in case of

emergency, instantly turns off the current and applies powerful brakes. The intensity of the brakes is increased as the handle is further raised. When the speed has been reduced, by again lowering the handle, any of the speed notches can be readily picked up; the speed and brake being always under instant control, *one hand only being engaged*. It is apparent that the current manipulation to the motor and brakes requires only an imperceptible effort. In production, the controlling handle is made either to stay where placed, or is self-raising to the brake position, to suit the fancy of the owner. The controlling handle lying nearly horizontal, the "aiming" action in steering (see Fig. 6) completes the simplicity of the operation.

The controlling head, which is shown in Figs. 9 and 10 is supplied with an indicator showing at all times the position of controlling cylinder. Fig. 9 shows first speed and Fig. 10 the third speed, and by touching a button on the side (seen in Fig. 11) the handle may readily be raised to position shown in the figure, for convenience of occupants, especially for getting in and out on the driver's side.

In crowded thoroughfares, the brake is the most important feature of the automobile. The French authorities in passing upon vehicles, insist upon this factor more than any other, and it is certainly the most indispensable. Whatever else the vehicle can or cannot compass, it must be possible to stop it, and that instantly, on occasions. The brake should be powerful and at least in duplicate. The carriages illustrated herewith are each provided with three separate brake systems.

The location of the controller beneath the foot board (as seen in Fig. 11) is found to present decided advantages in point of convenient interlock and inter-connection with the brakes. The motor cannot be started without first removing all the brakes. This location gives ready access at all times and upon all sides by the hinged floor; gives a natural interlock between the controller and the compound gear above referred to, and also between the controller and charging terminals, which are also here located. Numerous accidents and even wrecks have been caused by failing to open a special motor switch, when placing the controller in series position for charging. A simple interlock, with the charging terminals entirely eliminates this danger, and indeed the interlocking system throughout the carriage very thoroughly protects it in inexperienced hands; for instance, if the directing indicator

(seen in Figs. 2 and 12) is removed, the motor and controller are locked. If the index or pointer of this indicator points forward the vehicle will go forward. If to the rear, the vehicle will go backward. If it points upward, (as seen in Figs. 6, 9 and 11) the carriage may be charged, but when in this position, all the conductors of the motor cable are automatically open-circuited, preventing accident. The pointer can never be manipulated until the controller is first open-circuited, and if the index is only partially turned, through carelessness, or otherwise, the controller cannot be operated until the mistake has been corrected.

The motor being light and small, normally should be of relatively "high speed," still farther reducing the weight. A small motor is possible with the compound gear. The double reduction motor possesses advantages of allowing the hand-brake to be operated on the intermediate shaft, thus working through the compensating gear. A small brake, in this way, gives all the leverage necessary, being one reduction back through steel gears with small peripheral velocity, thus acting without noise. Another advantage of double reduction is in keeping all the gears of the power system small, and thus ensuring a neater appearance. The somewhat higher speed permissible in the double reduction arrangement also renders possible the bipolar motor, with its higher efficiency, as compared with the multipolar. Every condition tending to higher efficiences should be considered in connection with automobile equipment, as conserving the resources of the battery. These conditions are not as necessary with systems of tram traction, where the prime source of power is always available.

The location of the controller and current-manipulating switches low, (as seen in Fig. 11) and in front of the batteries, avoids hydrogen detonation and eliminates all danger of explosion from spark or opening circuit.

Much has been said of one motor versus two. This is largely a matter of mechanics; it is conceded that one motor gives higher efficiency than two of half the power, and is less expensive to maintain. As even the heaviest strains are comparatively small, the compensating gear, where one motor is employed, is easily maintained, yielding a combination which is far simpler and employs less parts than with a double motor equipment.

The automobile will, for some time, necessarily be in the hands of the inexperienced and non-expert, and while it is not

possible to render it "fool proof," yet certain safeguards may be employed in and about its operating devices and charging system, which will materially reduce and almost prevent derangement. The manipulation may be be so thoroughly interlocked as to effectually prevent a wrong operation preceding the right one, and rendering it nearly impossible to make a mistake in anything like normal operation. Interlocks and safety devices are used in many branches of engineering; the introduction of automatic interlocking switches is a notable example, having placed steam railway operation on an entirely new basis. After subjecting these devices to continued practical test, and altering them until the requirements seem to have been met, the author is prepared to say that there is no reason why the important results reached in the interlocking switch and signal system, should not be compassed in automobile manipulation, and by devices vastly simpler and less expensive.

As to charging and care of batteries, it is believed that the differential wattmeter system for ordinary use, coupled with the periodic inspection by an expert from the home office or local headquarters, is the best arrangement now at our command. The author has found that the differential factor of the wattmeter should be adjustable, and should be brought from time to time into step with both the efficiency and charging curves of the battery. These curves change and are peculiarly altered by the time factors. These adjustments are easily made through determinations by the use of hydrometer. This can easily be one of the duties of the periodic inspection above referred to. The practical employment of the adjusting feature, or in fact, any device, by means of which the meter may be kept in step with the battery, is found to constitute such a meter an almost perfect safeguard against the destructive effects of overcharge and overdischarge in inexperienced hands. One tray of the batteries is shown in Fig. 13.

With the public conveyance, or a delivery system, operating a number of vehicles from one station, it may not be difficult to secure the services of a single expert attendant, yet for anything like commercial operation, the automobile itself must be entirely successful in the hands of the "raw recruit." Emphisis should by laid on the fact that the driver must be a man familiar, especially at first, with the routes and business in hand. The vehicle must be depended upon to perform successfully, even

under the most trying conditions, without demanding especial thought or attention on the part of its operator, who should simply be a good driver, and who, from an engineering standpoint, would be considered thoroughly non-expert.

Discussion.

Mr. Hermann Lemp Jr.:—The work of Mr. Sperry is well known. Yet it is well to know, that from personal information I have from Paris, his carriage was rated as A No. 1, and that in the land of the automobile.

Nor will it detract from his work if I say that of all automobile carriages to be built the electric carriage is the easiest. There is only one trouble: The storage battery. Our storage battery friends will say no, the trouble is everywhere else. In other carriages there may be a number of troubles but in the electric carriage there is only one; the storage battery.

Mr. Sperry has laid particular stress upon the value of a safe steering arrangement. I fully agree with him on that. The wheels of an automobile ought to be always locked completely and guarded against any strain from the road, and yet be practically free to be moved by the operator without any particular energy or skill on his part. We have operated a number of carriages by a hydraulic steering check, which need not be described at present.

I am rather surprised that Mr. Sperry should bring up the question of a change of gear. No doubt he has very good reasons for it but I think he himself this morning made the plea for simplicity in apparatus, and if there is anything that recommends an electrical carriage or a steam carriage, it is that there is only one thing to operate and not two or three. While Mr. Sperry operates all by one lever, I do not think it is real simplicity because it means introducing a number of devices which are apt to give tronble. The electrical carriage in my opinion is paramount in success for its simplicity, consisting only of a battery, a motor, a controller and a brake.

Mr. Sperry seems to be in favor of one motor. I think that is a subject open for discussion. It is said a differential gives no trouble but I think it does. If one of the wheels slips it will at once cause the other wheel to lose traction as well, whereas if the two wheels may be independently moved, one may slip while the other will do the work of two. For that reason, when a single motor is used I would prefer a clutch arrangement. I don't think I have anything more to add on the subject but may communicate a few more remarks later on.

Mr. C. W. Rice:—At page 518 Mr. Sever says the weight of the wagon complete is about one ton, so that the cost to run it is 18 cents per ton mile. Page 527, the weight two tons, and on page 530 he states it cost about five cents, that is two and

one half cents a ton a mile. So that makes a comparative cost between seven and eight times cheaper to operate the electric delivery wagon a mile, than the horse and wagon. The cost of charging in New York city for 14 kilowatt hours will be roughly forty cents. An electric wagon can run about 20 miles which checks up with these figures, making two cents per mile. There are about ten stations where electric wagons can be charged, so that the opportunity for the development of the electric automobile seems to be considerable.

MR. SPERRY:—The compound gear I think I endeavored to point out in the paper was introduced more as a safeguard to our weakest member, the battery; I want to say also about the valuable paper by Professor Sever, to which we have listened that I look upon it as setting up a mile stone marking progress. It shows where we are at the present time. We hope to gain still greater heights and I can assure you that there is work ahead for us all in that line. It is no easy problem, entertaining as it may appear; it is fraught with many practical difficulties, some of which Mr. Lemp has met, and it is worthy of our best mettle, and only by concerted efforts and the best engineering ability obtainable can we expect to equal the time-honored, and most honorable horse. His system of traction is unique, and nature has certainly provided him with a means of locomotion which in "draw-bar pull" is ideal. Again, we have had him so many years, I might say so many thousands of years, that he has become a part of our existence and civilization, and we must not hope to wholly displace the horse. But the demand of the municipalities and cleanliness of our streets, make it necessary that some better motor should be provided. It seems as Mr. Lemp has pointed out, the simplicity of the electric motor is its charm. There are fields for other motors, but we as electrical engineers are interested especially in the electric motor, and as I say we must work together shoulder to shoulder to gain one point after another, and I hope that when another year rolls around we may have indications that substantial progress will have been gained in this matter of displacing the horse in our streets.

MR. BLOOD:—In connection with the differential gear, I might state when you come to balance off weight for weight of motor with a double gear or a motor geared direct, you will find not very much saved. Take for instance three sizes of the motor which are necessary for all styles of carriage service, one of two horse power, one three and one five, the first one will weigh about 160 pounds with an armature speed of about 900 revolutions, the second 205 pounds and the third one 250 pounds. With an increase of about 50 per cent. you more than double the torque, double the output, and in order to double the output with differential gear, I do not think they will use more than 2 to 1 gear, the extra weight of the gear and the clutch mechanism and the

handle will come pretty near to 50 per cent. It amounts to somewhat the same thing in case of two motors versus one motor, although the arrangement there I think as Mr. Lemp says is due more to simplicity and ease in running, than to the weight. Although the differential clutch itself does not weigh anything like the increase in the weight of the two motors versus one; the arrangement necessary of the differential clutch entails other points in weight beside itself.

PROF. THOMSON:—The question seems to me to involve a sort of balancing between what you like to do and what you must do. The ideal arrangement seems to me to have traction on the four wheels, that is to give each of the forward wheels also a motor, as we can lighten the wheels, lighten the structure, and take off weight here and there from the rear wheels. When we put motors on the forward wheels I am not so sure but that that it would come to pretty nearly the same weight in the end, and when we consider that some of the wear and tear of the battery might possibly be saved by this arrangement, it becomes a proposition which we should consider. Of course, I realize the fact that the smaller the motor, the less the efficiency, but there are so many other factors that come in which it is difficult to estimate and balance, that it is worth while to consider all sides of the subject. At the same time it is probably possible to standardize the motors, and that of course conduces to low cost of manufacture. If I ever get an electric vehicle for my own use it will have traction on the four wheels. There is another reason why I say this and that is; in winter time when roads are slippery you want all the traction you can get, four wheels being none too many wheels to do the pulling, especially if you are on a hill rather icy, or if you are climbing over a snow bank. In such cases it does not seem very easy for the rear wbeels to push the forward wheels, but if the forward wheels have traction as well as the rear there is a better chance to get over obstructions.

MR. SPERRY:—I would like to say one word about the interesting feature of encountering snow. Last year when we had the enormous snow storms in New York, a representive followed these vehicles and the records they made were astonishing under the circumstances. A vehicle was also running in Cleveland all winter long, so as to get the effects there, and as a result of these two observations I might say that the motor vehicle is not stopped by snow. As Professor Thomson has stated, there could be no harm in constituting every wheel a driver. It is that kind of suggestion we want. And the best efforts of us all are none too good.

The Committee on Resolutions submitted the following report which was unanimously adopted:

Whereas, the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS at this, its 16th General Meeting, and its 185th consecutive meeting, held in the city of Boston, Massachusetts, June 26th, 27th and 28th, 1899, has been the recipient of many courtesies and privileges during its stay in Boston, which have greatly contributed to the interest, pleasure and profit of the members; Be it resolved;

First, that a vote of thanks be extended to His Honor, Josiah Quincy, the Mayor of Boston for the honor bestowed by his attendance at the opening ceremonies of the INSTITUTE and the felicitous expressions and appreciation of the work of the INSTITUTE as conveyed in his opening address, and for his courtesy in furnishing the steamer, J. Putnam Bradlee, in connection with the trip of the INSTITUTE to Pemberton, Nantasket and Braintree.

That a vote of thanks be extended to the Massachusetts Institute of Technology and the various professors thereof for the use of the Walker Building in which to hold the sessions of the INSTITUTE and for the various courtesies received during these meetings.

That a vote of thanks be extended to President Charles W. Eliot, Professor Ira B. Hollis, Professor John T. Trowbridge of Harvard University, and the members of the committee, Professor C. A. Adams, Jr., of the Lawrence Scientific School, W. F. Burke, S. E. Whiting, Professors Sabine and Hall of Harvard, Professor George F. Sever, of Columbia University, Dr. Hammond V. Hayes, Charles F. Hopewell, City Electrician, and others who rendered so enjoyable the visit of the INSTITUTE to Harvard University and Cambridge.

That a vote of thanks be extended to James T. Monroe, President, and members of the Technology Club for the invitation to our members to avail themselves of the privileges of the club during our stay in Boston.

That a vote of thanks be extended to W. A. Bancroft, President of the Boston Elevated R. R. for the use of the trolley cars placed at the disposal of the INSTITUTE in connection with its visits to the Terminal Station, the Boston Electric Light Station, Cambridge, the works of the New England Gas and Coke Co., Norumbega Park, to steamer landing, etc., also for the invitation extended to visit the Albany St, Harvard, Boylston and other power stations.

That a vote of thanks be extended to the Edison Electric Illuminating Co. for the invitation to inspect its five stations for supplying light and power.

That a vote of thanks be extended to the Boston Electric Light Co for the invitation to inspect their various stations for supplying light and power.

That a vote of thanks be extended to the officials of the Boston Terminal Company for the invitation extended to inspect the many engineering features at the Terminal Station.

That a vote of thanks be extended to the New England Gas and Coke Co. and to Messrs. G. H. Finn, General Manager; Louis J. Hirt, Chief Engineer and Dr. Schnievrina, chemist, for the courtesies in connection with the visit of the INSTITUTE to the works of that company.

That a vote of thanks be extended to the New England Electric Vehicle Transportation Co. and to Col. Albert A. Pope, for the use of the automobiles placed at the disposal of the INSTITUTE in connection with the visit to Harvard University.

That a vote of thanks be extended to Mr. E. W. Rice, Jr., Vice-President, and the General Electric Company, for the cordial invitation to visit the works of the company at Lynn, Mass., and Schenectady, New York.

That a vote of thanks be extended to Professor Elihu Thomson for his invitation for the INSTITUTE to visit informally his home at Swampscott, Mass.

That a vote of thanks be extended to the American Telephone and Telegraph Co. for the courtesy extended to the INSTITUTE in offering the free use of its long-distance telephone lines.

That a vote of thanks be extended to the New England Telephone and Telegraph Co. for placing at the INSTITUTE headquarters a telephone desk and set for free use of our members for Boston and suburban service, together with an invitation to visit their exchanges.

That a vote of thanks be extended to Edgar R. Champlin, Mayor of Cambridge, for the courteous invitation to visit the Manual Training School, pumping station and water works of the city of Cambridge.

That a vote of thanks be extended to Mr C. Atherton Hicks, President, for the courteous invitation to visit the opening ceremonies of the Needham and Boston Street Railway Company, Wednesday afternoon, June 28th.

That a vote of thanks be extended to Col. Heft and the officers of the N. Y., N. H. and H. R. R., for the use of a special train over the Nantasket branch of their road, and the invitation to inspect the details of both the overhead and third rail supply systems, power houses, etc.

That a vote of thanks be extended to the Boston Local Committee, Professor W. L. Puffer, Chairman; James I. Ayer, Vice-Chairman, and Messrs. Geo. W. Blodgett, Wm. Brophy, C. L. Edgar, W. C. Fish, A. V. Garratt, H. V. Hayes, Chas. F. Hopewell, Sidney Hosmer and Everett Morss for their most able and untiring efforts to make the stay of our members both pleasant and profitable.

WILLIAM J. HAMMER,
H. WARD LEONARD,
W. D. WEAVER,
Committee.

THE PRESIDENT:—In adjourning this meeting I want to say that I think we have had a very successful meeting. We have had very valuable papers and discussions, and I can only hope that when the INSTITUTE next comes to Boston it will maintain the record here established. We have every reason to congratulate ourselves and to thank everybody for entertaining us.

On motion the meeting then adjourned *sine die*.

Associate Members Elected at Executive Committee Meeting, August 23rd, 1899.

Name	Address	Endorsed by
BURKETT, CHAS. WATSON	Assistant, Engineering Dept. Southern Bell Tel. & Tel. Co., 87 South Pryor St., Atlanta, Ga.	J. P. Jackson. J. A. Wotten. F. A Pickernell.
CLARK, WM. EDWIN	With Clark and Mills, Engineers & Contractors, residence, 1440 Mass. Ave., Cambridge, Mass.	Jas. I. Ayer. C. A. Adams. Ralph W. Pope.
DUBOIS, TUTHILL	Electrical Mechanic, N. Y. Navy Yard, 2205 Pitkins Ave., Brooklyn, N. Y.	M. Osterberg. E. R. Knowles. Jas. Hamblet.
GOODMAN, WM. GEO. TOOP	Electrical Engineer, Tramway Construction under N. S. W. Government, Public Works Dep. residence, 86 Bondi Road, Sydney, N. S. W.	G. J. Fischer J. S. Fitzmaurice. S. W. Childs.
HALL, FRED'K A.	In Draughting Room, Westinghouse E. & M. Co., residence, 6033 Stanton Ave., Pittsburg, Pa.	H. Lemp. Thorburn Reid. John B. Blood.
HALLBERG, J. HENRY	Electrician & Designer of Arc Lamps with Standard Thermometer & Electric Co., Peabody, Mass., residence 151 Lafayette St., Salem, Mass.	T. C. Martin. C. C. Chesney. Jos. Wetzler.
HEFT, N. H.	Chief of Electrical Dept. N. Y. N. H. & H. R. R., New Haven, residence Bridgeport, Conn.	E. C. Boynton. E. E. Higgins. R. W. Pope.
HEWLETT, ERNEST HOLCOMBE	Electrical Engineer in Chief Control Rockhampton Gas & Coke Co., Ltd., residence Estoril Rockhampton, Queensland, Australia.	Arthur W. Jones. G. J Fischer. Ralph W. Pope.
LANSINGH. VAN RENSSELAER	Electrical Engineer, Western Electric Co., residence 5109 Kimbark Ave, Chicago, Ill.	A. H. Ford. H. H. Wait, Gerard Swope.
MCLAIN, RALPH CLAPP	Assistant Engineer to Constructing Engineer, Naughton & Co., residence 126 East 23rd St., New York.	R. H. Mansfield. F. J. Sprague. A. W. Berresford.
NAPHTALY, SAM. L.	Manager and General Superintendant The Central Light & Power Co. Room 500, Parrott Building, San Francisco, Cala.	N. S. Keith. F. G. Cartwright. A. E. Brooke Ridley
RYERSON, WM. NEWTON	Switchboard Attendant, Metropolitan Street Railway Co., residence 832 West 56th St., New York.	C. O. Mailloux. E. N. Carichoff. G. H. Hill.
STEWART JOHN BRUCE	Superintendent, Electric Plant Virginia Hot Springs Co., Hot Springs, Va.	L. G. Lilley. C. Stowe Reno. Bert L. Baldwin.
WALLER, CHAS. WAITE	Sales Agent, General Electric Co., Boston, Mass.	Sidney B. Paine. Chas. B. Burleigh. Edwin W. Hammer.
WILSON, H. S.	Superintendent, Puebla Electric Light Co., Puebla, Mexico.	J. B. Cahoon. J. R. Lovejoy. R. W. Pope.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

NEW YORK, September 27th, 1899.

The 136th meeting was held this date at 12 West 31st Street, and was called to order by President Kennelly at 8.15 P. M.

THE PRESIDENT:—The Secretary will read the announcements for the evening.

THE SECRETARY:—At the meeting of the Council held this afternoon the following foreign members were elected:

Name	Address	Endorsed by
CAMPBELL, HENRY ARTHUR	Electrician Jamaica Electric Light & Power Co., Ltd., 38 Harbor St., Kingston, Jamaica.	H. C. Wilson. R. W. Pope. T. C. Martin.
DAVIS, LESLIE FOSTER	Secretary and Manager, Jamaica Electric Light & Power Co., Ltd., 38 Harbor St., Kingston, Jamaica.	H. C. Wilson. R. W. Pope. T. C. Martin.

Total 2.

The following associate members were transferred to membership:

WILLIAM ENOCH MOORE,	General Superintendent and Electrician, The Augusta Railway and Electric Co., Augusta, Ga.
HENRY M. HOBART,	Engineer, care British Thomson Houston Co., London, England.
G. SACCO ALBANESE,	Electrical Engineer, Tramways Electrique de Nice, Nice, France.

At the same meeting the Secretary was instructed to have printed an edition of one thousand copies of the Standardization Committee's Report. It appeared in its perfected form in the June and July number of the TRANSACTIONS which has been circulated. I make this announcement in order that members who require separate copies in their work may procure them at the nominal price. That is, the retail price has been fixed at ten cents and five cents in quantities of ten or more. The pamphlet as it now appears has been revised thoroughly by this committee and was finally adopted by the meeting at Boston. It appeared as a preliminary report, as you may remember, over a year ago and was discussed at Omaha.

THE PRESIDENT:—The paper for this evening is upon "Series Arc Lighting from Constant Current Transformers" by Prof. Robb who is present and we shall be pleased to hear from him.

A paper presented at the 136th Meeting of the American Institute of Electrical Engineers, New York, September 27th, 1899. President Kennelly in the Chair.

[ADVANCE COPY SUBJECT TO REVISION.]

SERIES ARC LIGHTING FROM CONSTANT CURRENT TRANSFORMERS.

BY WM. LISPENARD ROBB.

In all long-distance transmissions of electricity, and when large areas are supplied from a single advantageously located power plant we must, at least in the present state of the art, generate and transmit alternating current.

In general it will be found desirable in my opinion to supply current to the street lights from the same secondary mains that supply the current for the commercial lighting and power. There are, however, in most places large districts in which the streets are lighted by arc lamps, and where there is no commercial lighting or power. These sections can be most economically lighted by series arc lights.

Various methods of operating series arc lamps from alternating current systems have been suggested, and are in successful operation.

In several well-known stations in this country, continuous current series arc dynamos are driven by synchronous or induction alternating current motors, the arc dynamos being either direct-connected to motors or belted from a line shaft which is driven by motors. In England, direct-current series arc lamps are operated successfully from rectifiers. In 1896 the Hartford Electric Light Company, with which I am associated, decided that it would be advantageous to make a radical change in its system of series arc lighting, with a view to obtaing a greater economy of operation. The series commercial arc lamps and the street lamps in the same section of the city were changed over from series open-air arc to constant potential arcs. It was considered advisable to continue the series arc lamps for lighting

the outlying portions of the city. Propositions were considered both for using motor-driven series arc dynamos and for using rectifiers.

An order was finally placed with a manufacturer for a rectifier. A satisfactory rectifier never materialized, and we were unsuccessful in our attempts to import one from Europe.

The development of the enclosed arc lamp quickly led to the evolution of a satisfactory alternating current arc lamp of the constant potential variety. The perfection of this lamp led Mr. Richard Fleming, one of the engineers of the manufacturing company, to suggest the advisability of operating series alternating arc lamps from the constant-current transformer, which formed one of the essential parts of the rectifier.

An experimental transformer having a capacity for operating 30 lights in series, was installed in April, 1898. After being subjected to a thorough test in the central station it was put in practical operation on a street circuit. The results of these tests were so satisfactory that an order was soon placed for several transformers each having a 100-light capacity. The first of these transformers was installed about a year ago and during the year all of the continuous-current series arc dynamos have been replaced by constant-current transformers.

It has seemed to me that it would be of value to some of the members of the INSTITUTE if the data obtained in the operation of these transformers was made a matter of record in the proceedings.

THE CONSTANT CURRENT TRANSFORMER.

Each transformer is enclosed in a cylindrical tank. The tanks were originally made of boiler iron riveted up, but it proved impossible to keep these tight against the transil oil in which the transformer is immersed. The tanks are now made of cast iron.

The core of the transformer is of the sheet type, with a large central vertical core rising the whole height of the tank. This central core is surrounded by the primary and secondary coils and the magnetic circuit is closed by return paths outside the coils. In the transformers as made by the General Electric Company there are two primary and two secondary coils. One of the primaries is fixed at the bottom, and the other at the top of the central core. The two secondaries are free

to move up and down between the primary coils, and are so connected together that when one falls the other rises. They may approach into contact with each other at the middle of the tank, or from this position one may rise toward the primary coil at the top, while the other falls toward the primary coil at the bottom. Connected with the chains by which they are balanced is a lever which extends outwardly from the top of the oil tank and carries depending from its outer end a heavy adjustable weight. The lever is supported on a hardened steel knife-edge. This weight tends to force the two secondary coils respectively toward the two primary coils. When the transformer is in operation the currents induced in the secondary react upon those in the primary and tend to force the coils apart. This force is balanced for the desired normal current by the adjustable weight outside of the case. If the resistance of the secondary circuit falls,

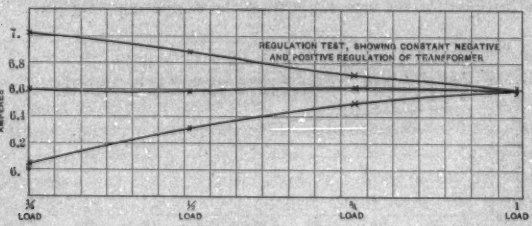

FIG. 1.

due to the cutting out of lamps, the current increases slightly, increasing the repulsion effect, and the secondary is pushed further away from the primary, giving a chance for increased magnetic leakage between the primary and the secondary, which reduces the E.M.F. in the secondary, bringing the current down to practically normal, even with wide changes of resistance. The regulation obtained is adjustable by means of a cam-shaped segment which can be moved on the outer end of the weighted lever.

The principle of regulation was first suggested by Prof. Elihu Thomson and its application to the operation of constant current transformers is broadly patented by him.

By bringing out the proper connections from the secondaries, the total number of lights may be operated as a single circuit, or operated in any desired number of multi-circuits in a manner similar to the well-known method employed on the Brush series dynamos of large capacity.

The larger sizes of this type of constant current transformers are always so arranged that the lights can be run on two circuits, or a single circuit, as may be desired. Owing to the high voltage of the enclosed arc lamp, the 100-light transformers usually operate two circuits connected upon the multi-circuit principle.

The transformer can be adjusted so as to give practically a constant current between one-third load and full load. As the properties of the transformer make it undesirable to run the transformer at less than one-third load, no attempt has been made to so construct the transformer that it would regulate under smaller loads. By adjusting the cam-shaped segment from which the counter-balancing weights are suspended, it is possible to regulate the transformer so that the current will increase or decrease as the number of lights is varied. The curves shown in Fig. 1 show the range of regulation that can be obtained by varying the adjustment of the cam supporting the regulating weights.

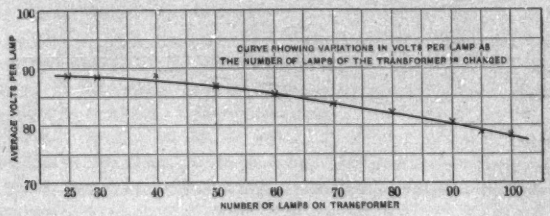

FIG. 2.

The early tests showed that when the transformers were adjusted to give a constant current through any desired range of load, that the lamps would draw different lengths on the arcs depending on the number of lamps on the circuit. The voltage across the terminals of the individual lamps was approximately 10 volts higher at one-fourth load than at full load, although the current was the same in both cases. The results of a test of a 100-light transformer made to show this effect is shown in Fig. 2. It has been found, however, that by varying the adjustment of the transformer, it is possible to adjust it so that the voltage across the terminals of the individual lamps remains practically constant at various loads. If so adjusted, however, the current from the transformer is no longer constant but increases as the load increases. The adjustment that maintains a constant voltage across the termi-

nals of the individual lamps seems the preferable one in those cases where the load of the transformer varies through a wide range. It is, however, of little practical importance in the operation of a street lighting circuit, as in that case the transformers are seldom operated in actual practice at less than 90 per cent. of full load.

Tests were made of the efficiency power factor and temperature rise of the transformers. The input and output of the transformers were measured with Weston wattmeters, ammeters and voltmeters, and were calibrated before and after test with standard laboratory instruments.

The averages of the results obtained from two 100-light transformers were as follows:

Load.	Efficiency.	Power Factor.
¼ Load ..	88.1	24%
½ "	92.3	44
¾ "	94.9	62
Full "	96.1	78

The rise in temperature of the oil of the transformer measured at the top of the iron core, where it was highest, was 39° C. after a twenty-four hour's run.

Under the usual conditions of street lighting, the dynamos are run under at least 90% of full load and at this load the efficiency and power factor are very satisfactory. The power factor is about as high as that of the induction motor under the average load at which they are operated.

The low power factor at fractional loads, and the difficulty in maintaining the lamps at constant voltage when the current is constant at various loads, combine to make the constant current transformer undesirable except when the conditions are such that it is possible to operate the transformer under a large part of its rated full load.

It has been found in practice, that the transformers can be maintained and operated successfully with very little attention. In Hartford five of the transformers are operated from two outlying sub-stations. There is no attendant at either of the stations. The inspector of the district cuts on and off the lights at the proper time and visits the sub-stations once during the night. Each transformer is equipped with a recording Bristol ammeter so that a complete record is made of the time of cutting on and off the circuits and of the time the inspector makes his nightly inspection, and of the working and adjustment of the

transformer. A record selected as being a fair representation of the daily records is given in Fig. 3. The primaries of the transformers are connected across the 2400-volt alternating current feeders. Although the voltage at the terminals of the primary of the transformer is subject to a variation of 5% during the street lighting hours, the current supplied to the series lighting circuits is practically constant. The transformer whose operation is recorded in Fig. 3, takes its current from the alternating

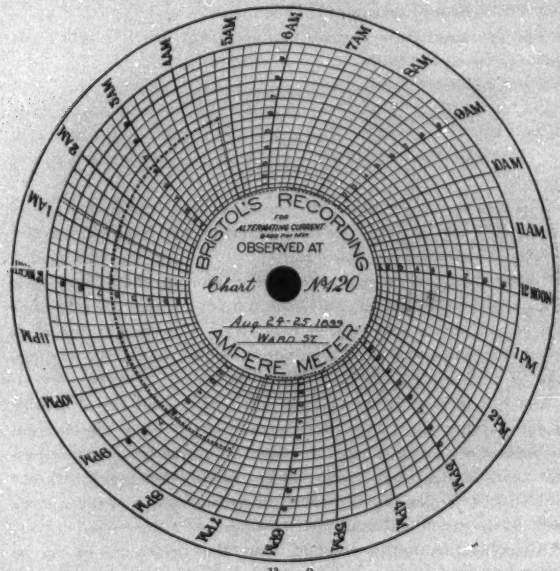

Fig. 3.

current lighting system about one mile from the central station. The current in the secondary is not affected by variations in the pressure at which current is supplied to the primary of the transformer.

The Series Alternating Arc Lamp.

The lamps operated from the constant-current transformer are of the carbon feed enclosed type. The alternating current used

has a frequency of 60 cycles. The operation of the lamp is on the differential principle.

The lamps at the outset gave a good deal of trouble. A considerable percentage of the lamps failed to start. This trouble was soon found to be due to the burning out of the sliding contact by which electric connection is made with the upper carbon. A positive contact is now made by means of a very flexible wire made of fine strands. Since this change the operation of the lamps has been in all respects satisfactory. The records show that the lamps reported out and not starting, are considerably less than they were when the street lighting was by direct-current series open-air arc lamps.

Unfortunately I have been unable up to the present to make any photometer tests of the candle power of the series alternating arc lamps. The lamps used in Hartford consume at the transformer 400 watts per lamp, and replaced nominal 1200 candle power open-air direct-current arcs. The streets are undoubtedly better lighted with series enclosed arc lamps than they were formerly with the open-air arcs. The better diffusion of the light from the enclosed arc lamp, the steadiness of the light and its freedom from flickering, have much to do with the improvement in lighting and with the general satisfaction it undoubtedly gives. From the results obtained at Hartford I am confident the streets can be better lighted with 400-watt series alternating lights, than with an equal number of nominal 1200 open-air direct-current arcs. If 2000 candle-power direct-current arcs were replaced by enclosed series alternating it would, in all probability, be necessary to increase the number of lamps in order to obtain equally good lighting.

Before the changes in the street lighting system the lamps were operated from Excelsior, Thomson-Houston and Brush series dynamos, belted from the line shaft. This was driven by a direct-connected synchronous motor. The power furnished the synchronous motor was 550 watts for each open-air arc lamp consuming 315 watts at the lamp. The power required under the local Hartford conditions for operating street lights has therefore been reduced by the change in the ratio of 550 to 400, or a little over 27%.

Owing to the fact that the transformers are operated from outlying sub stations the wiring system has been very much simplified, and the cost of carrying current across the underground dis-

trict considerably reduced. The maintenance of the transformers and the labor in looking after their operation is an almost negligible item. A very considerable saving is made over the maintenance and operation of the series direct-current dynamo. From experience extending now over a year it has become evident that the saving in operating expenses will pay for the entire cost of the change in system within the first two years. At the expiration of this time there will be a very considerable annual saving, and at the same time the service rendered the city is very much better than it was under the old system.

The system of street lighting which will be found best for any given city depends largely upon the local conditions, but there are undoubtedly many cases where an investigation will show that the adoption of the constant-current transformer and the series alternating current arc lamp offers the greatest advantages.

Discussion.

The President:—We have had a good deal of experience up to the present time with constant potential transformers, but the constant current transformer is an apparatus with which we are less familiar, and an opportunity to study its behavior has been afforded us in the paper which Professor Robb has just read. There is also a good opportunity to examine the apparatus and I am sure that Prof. Robb will only be too pleased to help us arrive at its relative merits and demerits

Mr. Charles Steinmetz:—An interesting feature mentioned in Prof. Robb's paper is the change of wave shape with the load. This illustrates the futility of specifying sine waves in alternating generators as occasionally done. It shows that the receiving apparatus is instrumental also in determining and changing the wave shape. This is especially the case with arc lamps.

As known, the alternating arc can not be represented by a constant effective resistance, but has an effective resistance varying periodically with the current strength, with double frequency. The apparent resistance of the arc is very high at small currents, low at large currents, and varies almost inversely proportional to the current strength. In consequence thereof, if the current passing through an arc lamp is a sine wave, the potential difference can not be a sine wave, but is less near large values of current, and greater near small values of current, that is becomes double-peaked, and if a sine wave of potential difference is impressed upon the arc, the current can not be a sine wave but is less near small, greater near large values of potential difference, that is becomes single-peaked.

Let us see now what takes place in a constant current transformer. At full load with primary and secondary coils close together, the internal self-induction is relatively small, and the secondary E. M. F. wave is nearly the same as the primary, that is assuming a sine wave of impressed E. M. F. the secondary potential difference is sinusoidal, thus the secondary current single-peaked. At light load, however, the primary and secondary coils are widely separated, and the internal self-induction of the transformer very high. Thus by the effect of self-induction in suppressing the higher harmonics, the secondary current is maintained closely resembling sine shape, and in this case the secondary potential difference becomes double-peaked. Thus from no load to full load the shape of E. M. F. and current waves in the arc light circuit changes, but in no case can current and E. M. F. have the same shape, for instance both be sine waves.

Since the instruments read effective values, the regulating mechanism of the lamp, however, especially the shunt coil magnet, depends to a certain extent on the mean value of potential difference; with the change of form factor under load, the lamp regulation may slightly change.

If nobody takes the floor I should like to add a few remarks on the rectifier which has never realized. This rectifier was a 60-cycle single-phase apparatus and operated extremely satisfactorily carrying 50 to 60 lamps with absolute steadiness, from a motor-driven alternator, until I put it on the circuit of an alternator driven by a single cylinder engine with rather poor uniformity of the rate of rotation, realizing that such condition would have to be met in single-phase high frequency work. The result was that the rectifier never left the factory.

Since that time the conditions of application of such rectifiers have changed, and some are now in satisfactory commercial operation, one for instance in Brooklyn. In this the 25-cycle three-phase rectifier is supplied with power from large direct-connected alternators driving synchronous machines, that is of a very close speed regulation. Under these conditions the operation is perfectly satisfactory.

So you see we have two solutions of the problem of arc lighting from alternating circuits. Direct lighting by constant current transformers, and alternating lamps for circuits of 40 cycles and over, single-phase or polyphase, and lighting by rectifier and continuous current lamps for low-frequency polyphase circuits of 25 to 40 cycles.

Direct arc lighting at 25 cycles is not feasible, 40 cycles being about the limit, and rectification is undesirable on 60-cycle single-phase circuits, due to the pulsating nature of the rectified current.

If you put a continuous and an alternating ammeter and a continuous and an alternating voltmeter in such a rectified single-phase circuit and vary the load from short circuit to full load: at one extreme the ammeters fairly agree and the voltmeters disagree widely, then the disagreement of voltmeters becomes less and that of the ammeters more, and ultimately at the other extreme of load the voltmeters fairly agree and the ammeters disagree. But at any load the product of volts and amperes exceeds the watts by as much as 10 to 20%. The efficiency of the rectifying apparatus if calculated by volt-ampere output comes out too high by the same percentage.

Mr. J. H. Hallberg:—After considering Mr. Steinmetz's statement it seems as if in time we shall be able to take the alternating current by means of the rectifier, and succeed in getting a commercially successful direct current series arc lighting system operated by the large alternating generators, and in that way gain all the advantages which we gain by the series enclosed alternating system.

By what Mr. Steinmetz says it seems as if it would be possible to produce a successful rectifier, and if it is, there certainly is in my estimation more chance for the commercial success of the direct current series enclosed arc-lamp, at the present time than for the series alternating current lamp.

We have produced direct current enclosed series arc lamps with an efficiency of 97.3 per cent. That is a remarkably high efficiency. It is produced by a shunt lamp and it will regulate within six to eight volts, from cold to normal temperature, which is probably 210° F. Of course, I have followed with great interest the series alternating system, but I have never as yet had a chance to practice in it very much on a large scale; but, from what I can learn, nothing but the differential lamp has been applied as yet commercially to this system. Why should it not be well to experiment a little more with the shunt system and put it practically on the market? It seems to me that as the lag current is a great objection we could materially decrease the same by using a shunt lamp.

My trouble with A. C. enclosed shunt lamps has been in *starting* the circuit. The moment we throw the full current on the circuit of shunt lamps, if we do not use a dash-pot, we rupture the circuit instantly, for the reason that all the arcs are struck instantaneously, and it strains the generator and the transformer. I experimented with a small dash-pot in connection with the shunt lamp and succeeded in starting slowly, but by using it I sacrificed somewhat the regulation of the lamp on account of the sluggishness of the dash-pot. In the designing of arc lamps I have always tried to follow the method of doing away with the dash-pot, for the simple reason that the dash-pot is one of the most troublesome, as well as vital, parts of an arc lamp. I have succeeded in producing an enclosed arc lamp of the shunt type for constant current, A. C. series circuits which seems to be practical, without a dash-pot. Now, would there not be some advantage in applying this type of lamp to a system? Not being thoroughly familiar with the constant current transformer I shall not enter upon that subject at all, but simply from the arc lamp standpoint it seems if we could reduce the lag current and raise the power factor, we would be able to do much better than at present.

I have never made a test on a General Electric A. C. series lamp, but I presume they must have considerable lag current in the series coils. If we could do away with the wattless current in the lamps, and if the transformer would still continue to regulate as well as it does now with the assistance of the series lamp coils, wouldn't it be a better system?

MR. RICHARD FLEMING:—I would like to reply to the gentleman's reference to the power factor of the different lamps. The power factor of the differential lamp as seen by the curve of the transformer at full load, is very nearly 80 per cent. The power factor of the feed lamp at 60 cyles is 92 per cent. The efficiency of that lamp—I cannot give you the exact percentage, but a lamp consuming 425 to 450 watts at the terminals consumed 10 to 20 watts in the shunt magnet and about 2 or 3 watts in the small cut-out magnet. So you can see that it has a pretty

high percentage efficiency. The variation which takes place due to the wave form, which I believe to be the cause of it, is altogether overcome by the use of the shunt feed lamp. The load can be changed down to short-circuit on the transformer and the lamp, even though the current may increase, say three-quarters of an ampere to an ampere, due to the fact that no regulation is provided down below quarter load, no change whatever takes place in the lamp—no change which can be measured on an ordinary alternating voltmeter. That is, to say the least sufficiently close. Regarding the operation of the shunt feed lamp, the variations of the volts at the arc can be maintained within three volts on a lamp ordinarily adjusted for about 73 volts to the arc. Some lamps, perhaps, will increase just at the feeding point or at the tripping point of the clutch. This particular lamp that I have in mind is so designed that just before the tripping point it reduces the arc voltage about two volts, and when the clutch gets on the tripping point at the moment of release the voltage at the arc has reached about normal. So that judging from these figures, the operation of the lamp should be satisfactory. Regarding the starting of shunt lamps, there is absolutely no difficulty. There are a great many thousand shunt lamps, direct current, in operation, and I do not think that they have ever been known to cause any great difficulty in starting, and I will make the broad statement that the alternating lamp with the constant current transformer will start equally well. Dash-pots, of course, we use. They are one of the necessary evils of the arc lamp business. I suppose you are aware of that. So am I. But I will say this, that I think the trouble with dash-pots has been overcome by close attention to details and care in their manufacture. I will say that a great many thousands of these dash-pots are out at the present time, and the particular style I have in mind are operating most perfectly; in fact, I have yet to hear of more than one or two out of several thousands that have given trouble, and that not of a serious nature. So that the dash-pot question is hardly to be considered. The starting of the transformer was also mentioned as being a disadvantage. But that is a very easy matter. It is easier if anything to start into operation than an ordinary series arc dynamo. You can start it on the ground, having it in a station or a sub-station, or you can start it at a distance. A device has been designed for the latter purpose that does it most effectively. Any further questions I should be glad to answer

MR. HALLBERG:—I can bear out Mr. Fleming's statements fully. My experience has been practically the same. The only particular in which we differ is in reference to the dash-pots. Of course, I realize that since the introduction of graphite and a few other such materials the difficulty may have been overcome to a certain extent. I did not mean that it is the actual effect of the

dash-pot which interferes with the regulation of the lamp. It is the natural move of the dash-pot, which is sluggish, and will cause the mechanism to hang-up and work sluggish, that is,—cause four or five volts' variation at the arc.

I made, a year or a year and a half ago, 14 alternating shunt lamps. They operated in series on about 1100 or 1200 volts. In place of a transformer I used a regulator, and this regulator was constructed on the rheostat principle with small impedance coils across the segments, and the main solenoid connected in series with the circuit which automatically cut in or out these impedance coils. This system worked beautifully and with a very small wattless current. The efficiency tested out very highly and the regulation was perfect. The shunt lamp was used in this experiment. The only difficulty experienced was in starting the circuits as the lamps were not provided with dash-pots. By use of a special starting device the lamps were started without chattering or breaking the circuit. Of course, we realize in a differential lamp the carbons are together when the lamp is at rest, and the moment you put on the current they lift gradually.

In the shunt lamp the carbons are apart when the lamp is at rest, and when the current is turned on the carbons are forced together. The arc is struck by means of either a spring or gravity. If no dash-pot is used the carbons separate very quickly, and if a large number of lamps are in series, it might cause the circuit to break and the lamps would consequently chatter before starting. Would it be possible to start a series of shunt lamps without dash-pots on a constant current transformer?

MR. FLEMING:—I do not think it is advisable. It is possible. In fact I have operated a circuit of lamps without a dash-pot. But I will say this, that I believe the dash-pot is an improvement. On the point you raise of starting, however, it is possible to start without excessive chattering. We have operated lamps, as you say, across the terminals of an alternator by the use of a reactive coil, an apparatus exactly like a constant current transformer in which the coils are connected in series, which gives practically the same effect you mention. The effect would be the same. That operated well. We have not done anything with that to speak of for the simple reason that it has several disadvantages as against the constant current transformer. With the use of the constant current transformer it is possible to separate your arc circuits entirely from your primary mains having no connection electrically with your distribution system, and that without the use of an auxiliary static transformer.

MR. HALLBERG:—Of course I realize to the full extent the scientific piece of work we have on the platform, and I admire it. It is a beautifully working piece of apparatus, and I think it thoroughly practical. My only suggestion was the use of a shunt lamp.

Of course, in arguing these points we have a good many things to take into consideration. I am simply looking at it from the arc lamp standpoint. I have nothing to do with the transformer, and know nothing practically about it. I have tried to get hold of data and information in the last few years, but it has been rather scarce, and we had to do the best we could with what we had, and I think from what Mr. Fleming now states, it will not be impossible to see a nice shunt system in operation.

MR. C. O. MAILLOUX:—I would like to ask Prof. Robb if they ever had any open circuits, and what happened then. We know that open circuits occur with direct current series arc lamps. I would like to know what happens when he has them with this transformer. Its E. M. F. will of course tend to rise greatly, and some precautions are doubtless necessary.

I was impressed with the uniformity of the current as shown by the Bristol chart records. I have had made many records of the same kind with Bristol recorders on direct current arc circuits, and I think you will all agree with me that they do not compare in uniformity and steadiness with those that are shown this evening. The direct current arc machine usually has a slight fluctuation. The current will rise a tenth or two above the normal ampere value, and it will fall a few tenths below, and sometimes it does that so fast and so often that the resulting line is a broadened mark which occupies a space corresponding to three or four tenths or even half an ampere. In this case you will see on the chart that the line is not greater in width than one-tenth of an ampere. In fact it is scarcely wider, if at all, than the width of the pen mark, showing that the current is maintained at practically a uniform and steady value. It varies at certain points, but the variation is slow. The charts show notches where the current value is raised as a whole or lowered as a whole. That may be due to lamps being cut out. Perhaps Prof. Robb can explain these notches in the curve.

PROF. ROBB:—When the circuit opens, either one or two things happens. If it is simply an open circuit for example on the hanger-board, you can spring a cut-out across it, and the circuit will run through till next morning. Of course, if we have a line wire broken, the coils of the transformer immediately go together and you have the full voltage of the transformer in the circuit. In practice, we never have had any difficulty from that which amounted to anything. We never had any serious injury to any number of lamps arise from it. As regards those notches that occur in the curves quite frequently at times, I have noticed a slight change in the position due to the variation in frequency. I do not think, however, that is really due to a variation in the current, so much as to a variation in the recording device. As you all know, Bristol recording meters are very much affected by the frequency, and you will nearly always notice that when the ammeter is thrown in or out of circuit it comes back slightly

different on the Bristol ammeter. I think they are largely inaccuracies in the recording device—hysteresis of the recording device.

There is one point in connection with the operation of transformers where we expect to meet with difficulty in connection with the operation from sub-stations. Of course, it will happen in every station if your circuits go out. In fact we have had a difficulty which has annoyed us a good deal in the past. Our circuits are rather freely equipped with lightning arresters. On the alternating system we run large units with separate lightning arresters at each transformer, and we find, now that we have probably back of the system about 4,000 horse power, that after a severe stroke of lightning, if there is a rush of current it blows the fuses on the circuits. It has happened in those cases at times when fuses have gone on the particular circuits on which the sub-station was. But we simply throw the switch in the station and let it go; it goes all right, operating perfectly satisfactory under those conditions. I think there is one point that Mr. Fleming brought out which is a very important one, and that is, that in the operation of street circuits, the fact that any system to give satisfactory operation must have the street lighting circuits separate from the alternating current distribution. That is, if you use any other regulating device you must have a static transformer between the two systems, owing to the fact that in the operation of series circuits they are sure to be more or less grounded. It may interest Mr. Steinmetz to know that I made a test of the transformer, giving the results of regulation, not the particular curve that I showed this evening, but I got another which was practically the same, and also measured the wave-form of the electromotive force given by the generators, and it was almost a perfect sine curve, simply one harmonic present to a very small percentage, and the result is very much the same.

Mr. Steinmetz is much more encouraging about rectifiers this evening than he was two years ago. Two years ago the rectifiers worked beautifully. The only trouble was, I was invited to see the operation of a rectifier, and I waited fifteen minutes to see it start. The rectifier worked beautifully. I tried to bring out that what is good practice in one locality is not good practice in another. There are a great many circumstances in which it is not advisable to use as low a frequency as 25 cycles. Furthermore a system which will pay for the total installation in two years can be very readily changed when we get to rectifiers. If we get the rectifier and find it does not work satisfactorily we can change it. It does not pay to stick to motor-driven direct-current machines with the possibility that in two or three years we may be able to get rectifiers, when we can put something in the place of them that will pay for itself in the course of eighteen months or two years.

MR. STEINMETZ:—I do not want to be misunderstood. I wanted to bring out that both types of apparatus have their proper field of application, the rectifier for 25-cycle power distributions where the constant current transformer is not feasible, because it gives too low a frequency for arc lighting, while in a 60-cycle system by the use of a constant current transformer we can dispose of the rectifier. The rectifier finds the proper field in the 25-cycle system.

PROF. ROBB:—I think we agree perfectly.

MR. STEINMETZ:—We have heard a good deal about rectifiers abroad, and how beautifully they are operated, and have heard reports of tests of very high efficiencies. For that reason I referred to the power factor of the rectified circuit, since I suspect that some unusually high efficiency claims are due to measuring the volts and amperes, multiplying them with each other and calling that the output.

MR. FLEMING:—In regard to the question of operating arc lamps on 25 cycles, I will say I have made an enclosed arc lamp, and operated it to a certain degree of satisfaction on 25 cycles, and I believe that it is not at all impossible to operate these lamps at that frequency, especially for street lighting. It is not a pleasant light to look at. But we do not look at the sun ordinarily as we pass along the street. We do not look at the arc lamps either. At a distance of 50 to 100 feet the light is not bad. It flickers: you can see that disagreeable trembling of the arc, but for street lighting I believe it can be made a commercial success, where it is not necessary to have the great refinements of smooth, even lighting. Take it all in all, I believe that if I were operating the station I should prefer the 25-cycle arc outside, to a rectifier inside. At 40 cycles the alternating arc is perfectly satisfactory for street lighting, and anywhere from that to 140 which is about the limit of commercial frequency.

The question was asked, "what happens when the circuit opens on a constant current transformer?" The total secondary electromotive force is applied to the break. Recently I have devised a little cut-out that when such an accident occurs, will immediately open the circuit at the station, and short-circuit the secondary of the transformer. This can be made to give an alarm. If the transformer is in the station it will generally give its own alarm to a certain extent. It will move and can be seen by the attendant, but as a matter of fact constant current transformers are generally installed in a basement or similarly out of sight. But it is a simple matter to rig an alarm that will indicate an open circuit on the line.

A gentleman mentioned the fact that if rectifiers were possible it would be very advantageous to use D. C. lamps as against A. C. lamps. There is a good deal to be said on both sides of the question. In my mind there is no advantage in using the D. C. as the A. C. is equally effective if not more so, especially for street

lighting, as with two lamps, assuming an equal amount of energy the arc alternating lamp would be more satisfactory for street lighting and equally satisfactory for inside lighting. I think I can illustrate what I mean by a diagram. [See Fig. 4.)

If an arc lamp is suspended 25 ft. from the ground the relative distribution of light will be about as shown. Curves A and A′ represent approximately the curves of distribution of an alternating lamp, enclosed type; B and B′ show the distribution of light from a D. C. enclosed lamp while C and C′ give the characteristic curve of an ordinary open arc D. C. lamp. The curves of the enclosed lamp in both cases represent lamps equipped with reflectors as used for street lighting. It will be noticed that the open arc lamp has a much higher maximum at an angle of 45°

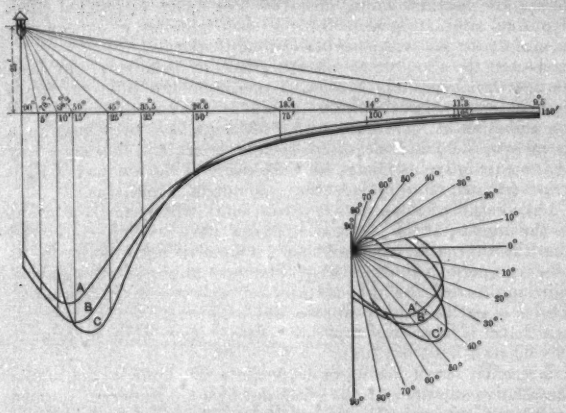

FIG. 4.

below the horizontal, and by referring to curve C (which is plotted according to the law that the amount of light is inversely as the square of the distance), it will be seen that this angle represents the distance from lamp of about 25 ft. At this point the illumination is much better from the D. C. lamp, open arc type, than from either of the others. At this angle the D. C. enclosed lamp comes second, while the alternating lamp is less than either.

At an angle of about from 25 to 30° below horizontal, the three lamps give illumination very nearly equal. This represents the distance from the lamp of about 50 ft. Beyond this point the light from the open arc lamp falls off very quickly. The D. C. enclosed lamp much less so, while the alrernating lamp gives more light than either. By referring to the curves it will be seen that at an angle of 10° below horizontal the alternating lamp

gives nearly twice as much light as the D. C open, while the D. C. enclosed is intermediate between the two, and approaching the alternating in luminosity though not quite reaching it. An angle of 10° below the horizontal represents a distance of very nearly 150 ft. from the lamp, at an elevation of about 25 ft. from the ground.

It should be noted here that the open arc lamps should be suspended as high as possible while the enclosed arc lamps should be hung as low as permissible. The usual practice in this respect is 20 ft. from the ground.

On account of characteristic distribution of light from the alternating lamp it is almost ideal for street lighting and especially where the distance between the lamps is considerable. Where lamps are installed more than 100 feet apart the general effect from an alternating lamp for the same amount of energy consumed at the arc will be superior to any other.

To test the above in actual operation an installation has been put up to determine the relative merits of the different lamps by making a comparison side by side. In the installation referred to, a number of the different kind of lamps have been hung in a large open field at a measured distance apart and in such a way that comparative estimates could be made of the amount of light given by each lamp under actual commercial conditions.

As a result of these tests, a great many who were skeptical as to the merits of the alternating lamps have become convinced that the alternating enclosed lamp is equal if not superior to its older competitors in every way. The most important thing about this lamp is that the light is thrown exactly where it is wanted. The D. C. enclosed lamp approaches it quite closely in this respect but it is in no way superior. Either lamp is far superior to the old style open arc lamp.

I recently saw a photograph made in St. Louis to determine the relative amount of light given out by a 9.6 ampere D. C. open arc lamp as against a 7½ ampere alternating enclosed lamp. Both lamps were adjusted to consume approximately the same number of watts at the arc.

A sign was made up especially for the occasion with white letters of varying height on a dark background. The sign was placed about 100 ft. from the lamp and a photograph made by means of the light from each lamp. On the photograph from the D. C. lamp the foreground was brilliantly lighted, while half way between the camera and the sign, the light stopped short. Beyond this point it could be very plainly seen that there was comparative darkness, it being barely possible to make out the outline of the sign and letters, and the surrounding buildings and other objects were represented by mere shadows.

With the alternating lamp it was quite different, not only was the sign well lighted, but the buildings were lighted up quite well, and a number of advertising signs could be clearly made

out. The foreground was not nearly as brightly lighted as with the D. C. lamp but the photograph shows an almost perfect distribution of the light to a considerable distance from the lamp. The exposure in each case was identical and the development purposely made the same, and everything possible was done to make the conditions equal. The exposure was about 20 minutes with the diaphragm of the lens set at F-16.

MR. HALLBERG:—When I made a remark in regard to the advantage of the direct current lamp over the alternating, I had reference to the *enclosed* direct current lamp. But, of course, now that Mr. Fleming has stated that the test was made on open arcs, I realize with the short arc it would not compare favorably at a distance with the alternating long enclosed arc. But if we take a direct current arc at 70 volts enclosed, at 6½ or 7 amperes and another of the same amperage and voltage at arc, on alternating current, we have two different cases,—one represents an arc approximately five-sixteenths of an inch in the direct current enclosed lamp. On the alternating current enclosed lamp we have an arc that is seven-sixteenths of an inch long. That bears out Mr. Fleming's idea of the distribution of the light. Where do we get it? In the alternating current we get the light from the arc itself;—we get very small craters on the alternating lamp, on account of interruptions on the circuit, depending upon the number of alternations, the light is practically extinguished as many times a minute as the alternations change. On the direct current enclosed lamp on the other hand, we have also got a long arc. The arc is much whiter than that of the alternating lamp, and in addition we have a crater on the upper carbon. I have not had a chance to investigate these tests which Mr. Fleming speaks of, and scientifically I have never had a chance to trace the curves or make a photometric test of them. But practically, I think that the direct current enclosed lamp will still hold its ground over the enclosed alternating, as far as illuminating power per watt is concerned.

Another little matter that figures very much in favor of the direct current lamp for the central station is, that the life of the direct current lamp is probably 125 to 150 hours, and the deposit on the inner globe at the end of that number of hours is no more than it is on the alternating lamp, which will only give a life of 75 hours. The carbons for the alternating lamp cost, if anything, more than they do for the direct current lamp. When we sum the two together, I still believe that the direct current enclosed arc lamp to-day holds the ground over the enclosed alternating lamp, providing the arc takes the same voltage and the same amperage, and if I should suggest a successful street lighting with alternating current, I should try to employ 7 to 7½ amperes.

MR. FLEMING:—Regarding the amount of light of the alternating and direct current enclosed lamps I have tried to show there, I did not bring out the merits of the direct current en-

closed lamp as fully as I might. The total difference in light between the D. C. and the alternating enclosed lamp is roughly about 10 or 15 per cent—I say roughly, advisedly, because we can only measure it roughly—it is about 10 or 15 per cent. in favor of the D. C. lamp. One thing that operates to the disadvantage of the D. C. lamp is the length of the arc. A D. C. lamp operating at 70 volts has a comparatively short arc, so short that the shadow thrown by the lower carbon is very pronounced. This can be shown by the band of light on the inner globe. There is a band around the enclosing globe at an angle below the arc, whereas with the alternating arc the distance apart of the ends of the carbon is quite great, In that way the light has a good opportunity to get out, and the shadows are not nearly so pronounced. The shadows of the carbons in the alternating lamp are not more than the necessary shadows thrown by the frame, and by the parts of the lamp itself. That 10 or 15 per cent. in favor of the D. C. lamp is more than made up by the curve of distribution of the light from the alternating lamp. That is, the maximum light is actually where it is needed at a distance, and not directly under the lamp. The alternating lamp is almost ideal in that respect, and has a great advantage over the D. C. lamp.

Another point of the alternating lamp—we all know that the negative carbon on the D. C. lamp is not consumed rapidly, and the arc remains practically in the same place. On that account the deposit on the globe is all located on the upper part of the globe, and after a while the drop in candle power is very pronounced. On the other hand with the alternating lamp the arc travels down—I do not exactly remember the relative proportion—several times as great—it is continually moving down into the cleaner portion of the globe. That is a fact that I have proved by actual photometric tests, and is very much in favor of the alternating lamp. It leaves the deposit on the top of the globe, and is continually moving down so that the light gets out under this deposit. That was suggested quite a while ago. I made tests to prove it, and I have on record a photometric test showing where an alternating lamp at an angle of about 45 degrees, I think it was, gave actually more candle power at the end of an 80-hour run than it did with a clean globe. That is putting it rather strong, but such is the fact. That is on record. That was due to the fact that the white, fleecy deposit which is so characteristic of the alternating arc, due I think, to the core, acted as a reflector and threw the light down, which was what we wanted, and the curve from that lamp at the end of the run was something like that of the D. C. lamp showing that the light upwards was cut off to a marked extent, while the light downward was increased, owing to the reflection from the inside of the globe and I think it is perfectly reasonable. Regarding the cost of carbon, there is very little difference between the two. The cost of trimming is about the same.

The current at the arc is a question which central station men will have to govern. It will have to be governed by local conditions, though I will say that a 6.6 ampere alternating lamp will hold its own against the nominal 1200-candle open air arc, and that the 7½ ampere lamp will more than hold its own against the nominal 2000-candle arc, or against the 6.6 or 7-ampere direct-current enclosed lamp.

MR. HALLBERG:—As regards the shadows of the enclosed direct current lamp: I think that this has been pretty well overcome by the means of suitable reflectors. We have had some very severe tests on this point, and found that absolutely no shadow would be shown under any of the lamps provided they were all equipped with the proper reflectors. As regards the weakness of the shadow with the enclosed A. C. lamp, it is caused by the weakness of the alternating arcs as compared with the direct arcs. The absence of a crater in the alternating arc is what accounts for the fainter shadows with the alternating than with the direct enclosed lamp. When we come to the matter of deposit on the inner globe, my experience has been that on the direct current the deposit travels up. On alternating current it fills the entire globe more evenly. If we take two globes, one direct and one alternating, at the end of their runs you will find that the direct current globe has got a very marked dark circle around the top, whereas the A. C. globe will have a much more even coating on the inside.

As regards the travelling down of the arc; of course, the alternating arc travels much more rapidly, because the carbons are consumed 50% quicker.

In regard to Mr. Fleming's statement that he obtained more candle-power out of an A. C. enclosed lamp, after 70 hours' burning than he did on the start of the run, I cannot argue this point as I was not present at the test, but it must be remembered that he admitted that the deposit followed with the arc, slightly behind it, consequently at the end of the run this deposit prevented a large percentage of the light, which should have been thrown up against the reflector, from being utilized. It should also be remembered that the upward rays of the A. C. lamp were put down as being strongly in favor of the A. C. lamp. According to this, after the A. C. lamp had operated a short time, we would sacrifice this good point.

The D. C. lamp gives double the life and needs less attention. I think that it is of more importance to a station to have a lamp that runs 125 to 150 hours than to have one that will run only 70 hours. It means 50% less labor in trimming.

For conclusion, I beg to say that it has been generally admitted that the D. C. arc is more powerful and more suitable for illumination than the A. C. arc, and until some new feature is brought out in favor of the A. C. system, it will be hard to convince the central station manager of its superiority, especially if we can produce a successful rectifier for the D. C. arc-lamp.

Mr. Mailloux:—I would like to move a vote of thanks to Prof. Robb for the very interesting paper which he has given us. It is a new revelation in street lighting, and I think that he has made out his case particularly well, when, besides showing the material success of the lighting he has also demonstrated that the economic results indicate that the plant will pay for itself in two years or less.

The motion was carried, and the meeting adjourned.

[CORRESPONDENCE—SUBJECT TO REVISION.]

COST OF ARC LIGHTING.

BY H. H. WAIT.

[*A communication in discussion of a paper by William Lispenard Robb, on Series Arc Lighting from Constant Current Transformers, read September 27th, 1899. New York and Chicago.*]

The tables in this paper, giving the comparative first cost and operating expenses of various arc lighting systems, were originally compiled in a rough form some little time ago in order to determine whether it would pay to build a large direct current arc machine suitable for direct driving by moderate speed engines. The subject has received some little attention lately, and it was thought worth while to complete the tables and submit them to the INSTITUTE for discussion.

In Prof. Robb's paper on the Hartford system of arc lighting, a comparison is made between a modern alternating current system and an old direct current system. Several other such comparisons have been published recently. It is obviously unfair to compare an antiquated direct current system with the latest type of alternating apparatus. In the tables an attempt has been made to compare the systems given on an equitable basis. A little more attention has, perhaps, been given to pointing out some of the failings of the alternating current systems, principally on account of the fact that such systems are more or less of a fad at the present time and their failings not so well-known, whereas there are very few electricians interested in the subject who could not discourse for hours on the failings of older forms of direct current systems. In referring to the alternating current systems as fads the intention is not to convey the opinion that the A. C. systems will not survive permanently or that they are not considerably better than direct current systems for a great many cases.

Prof. Robb makes the statement that the changes in the Hartford plant will pay for themselves in about two years, and it would appear from the tables that in some cases the more modern continuous current systems might replace older ones and pay for the changes in still less than two years. This question is so dependent on local conditions, however, that it is impossible to make any general statements.

It is hoped that the tables are in such form that an engineer can pick out several systems to compare for any given plant and avoid the labor of going through the entire subject.

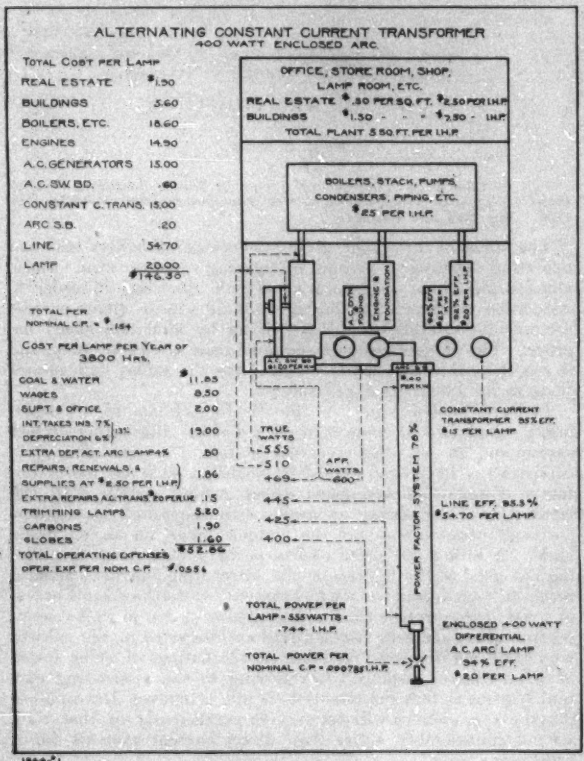

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FIG. 1. 950 Nominal c. p.

NOMENCLATURE.

In the tables the following letters have been used with the corresponding signification. It might be well to remark that it would be desirable to have the INSTITUTE sanction some such use as there is considerable confusion in the use of similar letters at present.

A. C. ..... Alternating Current
D. C. ..... Direct Current.
D. D. ..... Direct Driven.
C. C. ..... Constant Current.
C. P. ..... Constant Potential.
C. p. ..... Candle Power.

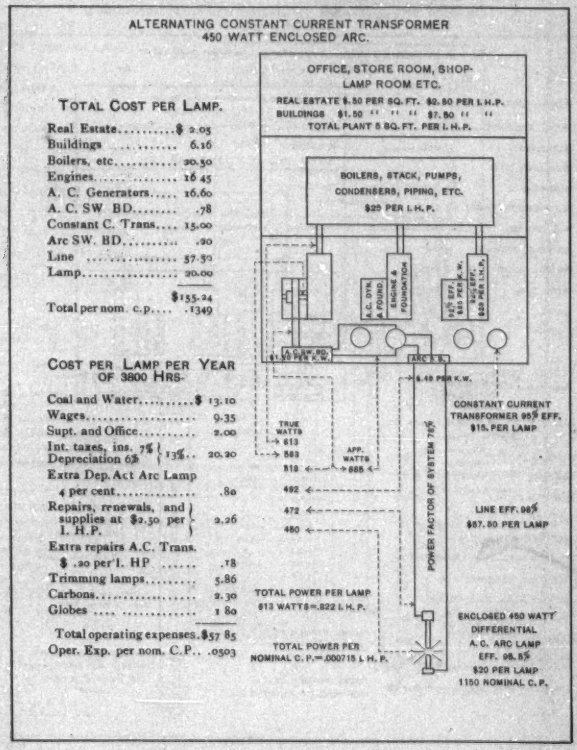

ALTERNATING CONSTANT CURRENT TRANSFORMER
450 WATT ENCLOSED ARC.
TOTAL COST PER LAMP.
Real Estate..... $ 2.05
Buildings 6.16
Boilers, etc..... 20.50
Engines..... 16 45
A. C. Generators..... 16.60
A. C. SW. BD..... .78
Constant C. Trans.... 15.00
Arc SW. BD..... .90
Line 57.50
Lamp..... 20.00
$155.24
Total per nom. c.p.... .1349
COST PER LAMP PER YEAR OF 3800 HRS.
Coal and Water..... $ 13.10
Wages..... 9.35
Supt. and Office..... 2.00
Int. taxes, ins. 7% Depreciation 6% 13%... 20.20
Extra Dep. Act Arc Lamp 4 per cent..... .80
Repairs, renewals, and supplies at $2.50 per I. H.P. 2.26
Extra repairs A.C. Trans. $ .20 per I. HP ..... .78
Trimming lamps..... 5.86
Carbons..... 2.30
Globes 1 80
Total operating expenses.. $57 85
Oper. Exp. per nom. C.P.. .0503
OFFICE, STORE ROOM, SHOP-LAMP ROOM ETC.
REAL ESTATE $.50 PER SQ. FT. $2.50 PER I. H.P.
BUILDINGS $1.50 " " " $7.50 " "
TOTAL PLANT 5 SQ. FT. PER I. H. P.
BOILERS, STACK, PUMPS, CONDENSERS, PIPING, ETC.
$25 PER I. H. P.
A.C. DYN. & FOUND
ENGINE & FOUNDATION
94% EFF. 1.5 P.F. K.W.
$40 PER I.H.P.
A. C. SW. BD. $1.50 PER K. W.
ARC L. B.
6.48 PER K.W.
CONSTANT CURRENT TRANSFORMER 95% EFF.
$15. PER LAMP
TRUE WATTS
613
583
APP. WATTS
818
885
492
472
480
POWER FACTOR OF SYSTEM 75%
LINE EFF. 96%
$57.50 PER LAMP
TOTAL POWER PER LAMP
613 WATTS=.822 I. H. P.
TOTAL POWER PER NOMINAL C. P.=.000715 I. H. P.
ENCLOSED 450 WATT DIFFERENTIAL A. C. ARC LAMP
EFF. 98.5%
$20 PER LAMP
1150 NOMINAL C. P.

FIG. 2.

The vital question in comparing alternating and direct current systems is the relative amount of power consumed for the same amount of light. There is a great diversity of opinion on this subject and good authority can be found for all sorts of factors.

In the tables the different types of lamps have been given the following ratings for the sake of comparision:

D. C. open arc,	450	watts	at	arc,	2000 c. p.
D. C. enclosed arc,	450	"	"	"	1500 "
A. C. enclosed arc,	450	"	"	"	1150 "
A. C. enclosed arc,	400	"	"	"	950 "
D. C. open arc.	300	"	"	"	1200 "
D. C. enclosed arc,	300	"	"	"	900 "

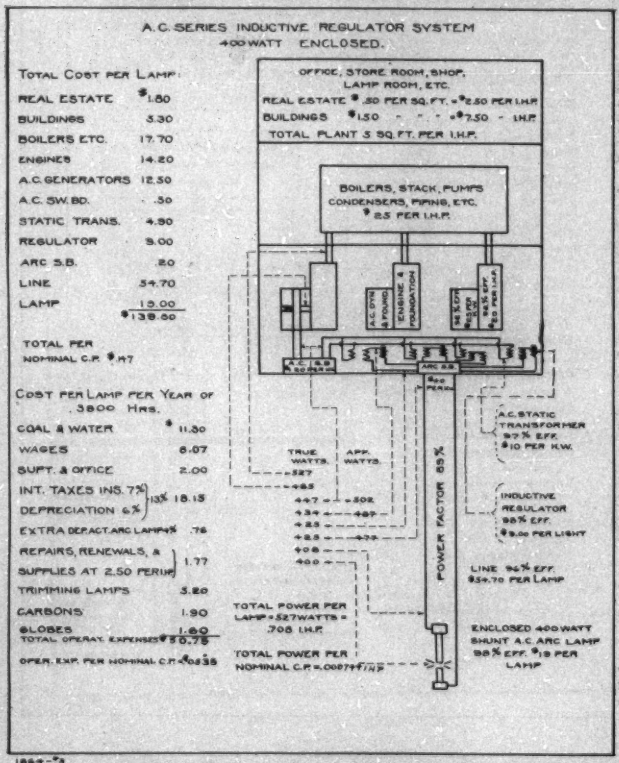

A.C. SERIES INDUCTIVE REGULATOR SYSTEM
400 WATT ENCLOSED.
TOTAL COST PER LAMP:
REAL ESTATE $1.80
BUILDINGS 5.30
BOILERS ETC. 17.70
ENGINES 14.20
A.C. GENERATORS 12.50
A.C. SW. BD. .50
STATIC TRANS. 4.90
REGULATOR 9.00
ARC S.B. .20
LINE 54.70
LAMP 15.00
$138.50
TOTAL PER NOMINAL C.P. $.147
COST PER LAMP PER YEAR OF 3800 HRS.
COAL & WATER $ 11.30
WAGES 8.07
SUPT. & OFFICE 2.00
INT. TAXES INS. 7% 13% 18.13
DEPRECIATION 6%
EXTRA DEFACT. ARC LAMPS 4% .76
REPAIRS, RENEWALS, & SUPPLIES AT 2.50 PER H.P. 1.77
TRIMMING LAMPS 3.20
CARBONS 1.90
GLOBES 1.60
TOTAL OPERAT. EXPENSES $50.75
OPER. EXP. PER NOMINAL C.P. $.038
OFFICE, STORE ROOM, SHOP, LAMP ROOM, ETC.
REAL ESTATE $.50 PER SQ. FT. = $2.50 PER I.H.P.
BUILDINGS $1.50 - - - - $7.50 - I.H.P.
TOTAL PLANT 3 SQ. FT. PER I.H.P.
BOILERS, STACK, PUMPS CONDENSERS, PIPING, ETC. $2.5 PER I.H.P.
A.C. DYN. & FOUND. ENGINE & FOUNDATION
96% EFF. $2.50 PER I.H.P.
A.C. & S.B. $.50 PER H.P.
ARC S.B.
800 PER H.P.
A.C. STATIC TRANSFORMER 97% EFF. $10 PER K.W.
INDUCTIVE REGULATOR 98% EFF. $9.00 PER LIGHT
LINE 96% EFF. $54.70 PER LAMP
ENCLOSED 400 WATT SHUNT A.C. ARC LAMP 98% EFF. $18 PER LAMP
TRUE WATTS. APP. WATTS.
527
485
447 = 502
434 = 487
423 =
425 = 477
408 =
400 =
POWER FACTOR 89%
TOTAL POWER PER LAMP = 527 WATTS = .706 I.H.P.
TOTAL POWER PER NOMINAL C.P. = .0027+ H.P.
1864-'93

FIG. 8. 950 Nominal c. p.

It is unfortunate that the 2000 and 1200 c. p. ratings of 450 and 300 watts respectively, adopted by most plants do not refer to the watts at the arc, but seem to include some small loss in

the mechanism. It has been thought advisable for the sake of definite comparison to give these ratings to open arcs, the watts being taken at the arc itself and corrections being made for the relative efficiency of the mechanism for different types of lamp. To arrive at an equitable figure for comparing the enclosed A. C.

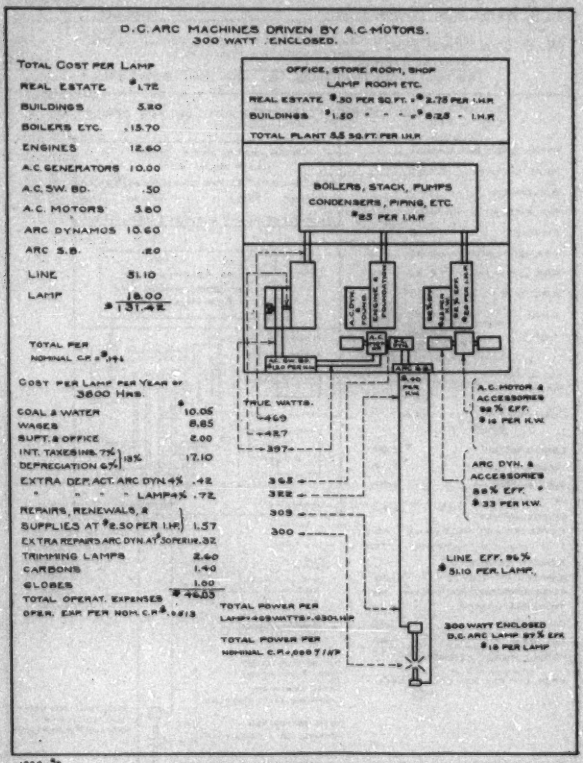

D.C. ARC MACHINES DRIVEN BY A.C. MOTORS.
300 WATT ENCLOSED.
TOTAL COST PER LAMP
REAL ESTATE $1.72
BUILDINGS 3.20
BOILERS ETC. 15.70
ENGINES 12.60
A.C. GENERATORS 10.00
A.C. SW. BD. .50
A.C. MOTORS 3.80
ARC DYNAMOS 10.60
ARC S.B. .20
LINE 51.10
LAMP 18.00
$131.42
TOTAL PER NOMINAL C.P. $.141
COST PER LAMP PER YEAR OF 3800 HRS.
COAL & WATER 10.05
WAGES 8.85
SUPT. & OFFICE 2.00
INT. TAXES INS. 7% DEPRECIATION 6% 13% 17.10
EXTRA DEP. ACT. ARC DYN. 4% .42
" " " LAMPS 4% .72
REPAIRS, RENEWALS, & SUPPLIES AT $2.50 PER I.H.P. 1.57
EXTRA REPAIRS ARC DYN. AT 30 PER I.H.P. 32
TRIMMING LAMPS 2.60
CARBONS 1.40
GLOBES 1.00
TOTAL OPERAT. EXPENSES $46.83
OPER. EXP. PER NOM. C.P. $.0313
OFFICE, STORE ROOM, SHOP
LAMP ROOM ETC.
REAL ESTATE $.30 PER SQ. FT. = $2.75 PER I.H.P.
BUILDINGS $1.50 " " " = $3.25 " I.H.P.
TOTAL PLANT 3.5 SQ. FT. PER I.H.P.
BOILERS, STACK, PUMPS
CONDENSERS, PIPING, ETC.
$25 PER I.H.P.
TRUE WATTS.
469
437
397
365
322
309
300
A.C. MOTOR & ACCESSORIES 98% EFF. $10 PER K.W.
ARC DYN. & ACCESSORIES 88% EFF. $33 PER K.W.
LINE EFF. 96% $51.10 PER LAMP.
300 WATT ENCLOSED D.C. ARC LAMP 87% EFF. $18 PER LAMP
TOTAL POWER PER LAMP = 469 WATTS = .630 I.H.P.
TOTAL POWER PER NOMINAL C.P. = .0007 I.H.P.

FIG. 4. 900 Nominal c. p.

and D. C. lamps with the open arcs, resort has been made to an average of the information at hand on this subject. In comparing direct current open and enclosed arcs the following figures were used:

			Ratio.
E. Thomson, *Elec. World*, June 12, '97,	W. per m.s.c.p.	open arc, 1.2	.69
" " " " "	"	enc. arc, 1.74	
L. B. Marks, " " Feb. 6, '97,	"	open arc, .95	.815
" " " " "	"	enc. arc, 1.17	
Pierron, *Elec. Review*, Mar. 5, '97,	"	open arc, .577	.65
" " " " "	"	enc. arc, .886	
L. B. Marks, Elec. Congress '93,	"	open arc, .84	.72
" " " " "	"	enc. arc, 1.17	
W. D. Steel, Street Test.			.82
General Average,			.739

This ratio is practically 75%, the value used in the tables.

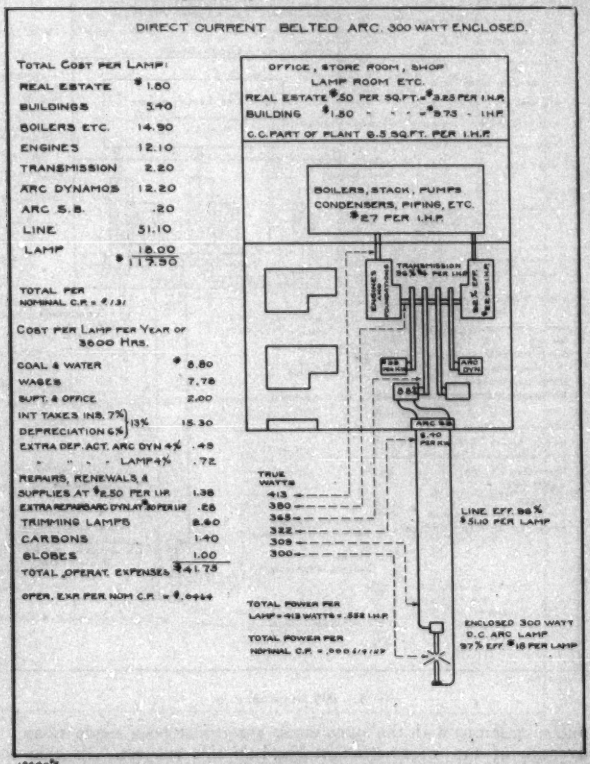

DIRECT CURRENT BELTED ARC. 300 WATT ENCLOSED.
TOTAL COST PER LAMP:
REAL ESTATE $ 1.80
BUILDINGS 5.40
BOILERS ETC. 14.90
ENGINES 12.10
TRANSMISSION 2.20
ARC DYNAMOS 12.20
ARC S.B. .20
LINE 51.10
LAMP 18.00
$ 117.50
TOTAL PER NOMINAL C.P. = $ 1.31
COST PER LAMP PER YEAR OF 3600 HRS.
COAL & WATER $ 8.80
WAGES 7.78
SUPT. & OFFICE 2.00
INT. TAXES, INS. 7% DEPRECIATION 6% 13% 15.30
EXTRA DEP. ACT. ARC DYN 4% .48
" " " " LAMP 4% .72
REPAIRS, RENEWALS, & SUPPLIES AT $2.50 PER I.H.P. 1.38
EXTRA REPAIRS ARC DYN. AT $30 PER I.H.P. .28
TRIMMING LAMPS 2.60
CARBONS 1.40
GLOBES 1.00
TOTAL OPERAT. EXPENSES $ 41.75
OPER. EXP. PER NOM C.P. = $ 0.046
OFFICE, STORE ROOM, SHOP LAMP ROOM ETC.
REAL ESTATE $.50 PER SQ.FT. = $ 3.23 PER I.H.P.
BUILDING $ 1.50 " " " = $ 9.73 " I.H.P.
C.C. PART OF PLANT 6.5 SQ.FT. PER I.H.P.
BOILERS, STACK, PUMPS CONDENSERS, PIPING, ETC. $ 27 PER I.H.P.
ENGINES
TRANSMISSION 96% PER I.H.P.
96% EFF. $ 2.50 PER I.H.P.
ARC DYN.
ARC S.B. $ .20 PER I.H.P.
TRUE WATTS
413
380
363
322
309
300
LINE. EFF. 98% $ 51.10 PER LAMP
TOTAL POWER PER LAMP = 413 WATTS = .552 I.H.P.
TOTAL POWER PER NOMINAL C.P. = .552 ÷ 1.31
ENCLOSED 300 WATT D.C. ARC LAMP 97% EFF. $ 18 PER LAMP

FIG. 5. 900 Nominal c. p.

*The value given is 1.94 at end of run; assuming that the average absorption of the globe would be 10% less, gives the figure taken.

If the mean hemispherical candle powers had been taken, the ratio would have been more advantageous to the open arc, but the distribution is so much more even with the enclosed arc that the lighting is generally more serviceable and consequently the mean spherical values were thought to give a reasonably fair basis of comparison.

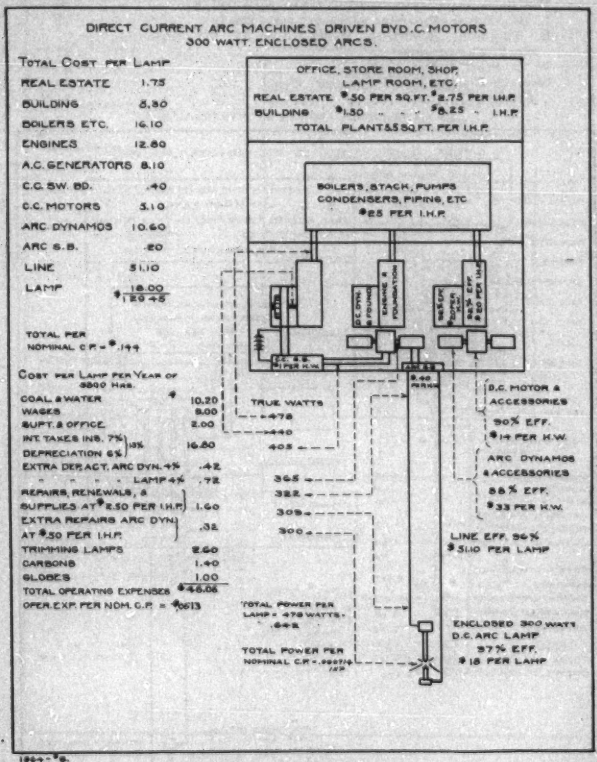


Fig. 6. 900 Nominal c. p.

For commercial lighting in stores, the superior distribution and steadiness of an enclosed arc undoubtedly give it so many advantages that for these cases it should be rated on a par with the open arc. For street lighting, however, the volume and intensity

of the light are more important than the quality, and as the tables refer more especially to systems serviceable for street lighting, the above ratio was taken.

There is very little reliable information at hand for comparing A. C. and D. C. enclosed lamps. The ratio was obtained as follows:

	Excess Watts per m.s. c.p. for A. C. over D.C.
Matthews, *et al*, TRANSACTIONS 1898, pages 605, 615,	52
L. B. Marks, Discussion of above, page 724	35
E. Thomson, *Electrical World*, June 12, '97, correcting for blackening of globe	21
W. D. Steel, Street Test	27
Western Electric Co., Laboratory Test	39
Average	34.8

33⅓% has been taken as a convenient ratio.

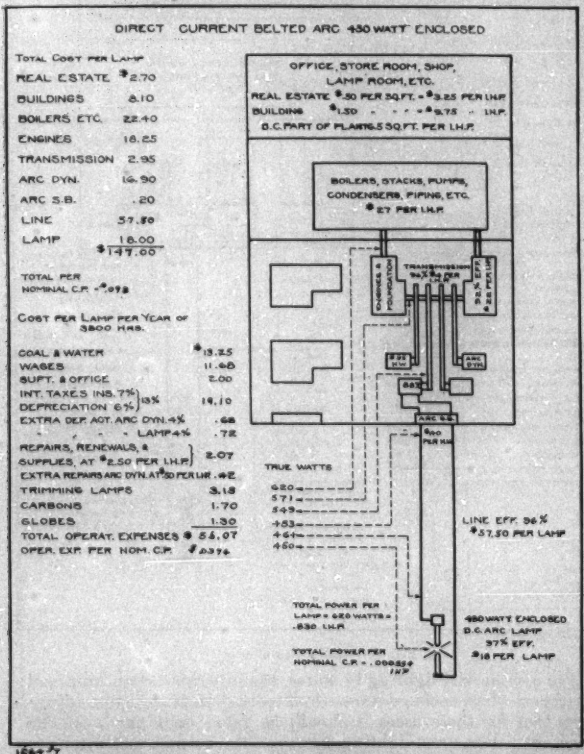
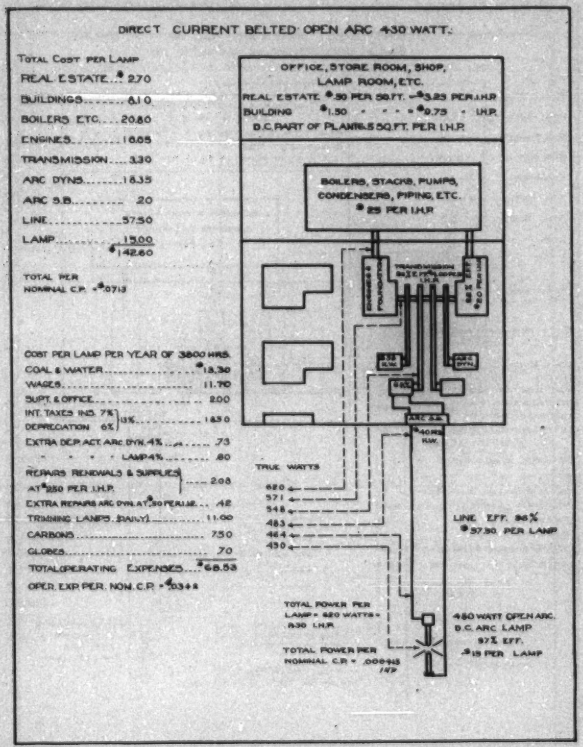

DIRECT CURRENT BELTED ARC 480 WATT ENCLOSED
TOTAL COST PER LAMP
REAL ESTATE $2.70
BUILDINGS 8.10
BOILERS ETC. 22.40
ENGINES 18.25
TRANSMISSION 2.95
ARC DYN. 16.90
ARC S.B. .20
LINE 57.50
LAMP 16.00
$147.00
TOTAL PER NOMINAL C.P. = $.098
COST PER LAMP PER YEAR OF 3800 HRS.
COAL & WATER $13.25
WAGES 11.65
SUPT. & OFFICE 2.00
INT. TAXES INS. 7% DEPRECIATION 6% 13% 19.10
EXTRA DEP. ACT. ARC DYN. 4% .68
" " " LAMP 4% .72
REPAIRS, RENEWALS, & SUPPLIES, AT $2.50 PER L.H.P. 2.07
EXTRA REPAIRS ARC DYN. AT $.50 PER HR. .92
TRIMMING LAMPS 3.18
CARBONS 1.70
GLOBES 1.30
TOTAL OPERAT. EXPENSES $ 56.07
OPER. EXP. PER NOM. C.P. $.0374
OFFICE, STORE ROOM, SHOP, LAMP ROOM, ETC.
REAL ESTATE $.50 PER SQ.FT. = $3.25 PER I.H.P.
BUILDING $1.50 " " " = $9.75 " I.H.P.
D.C. PART OF PLANT 6.5 SQ.FT. PER I.H.P.
BOILERS, STACKS, PUMPS, CONDENSERS, PIPING, ETC. $27 PER I.H.P.
ENGINES & FOUNDATION
TRANSMISSION 24.5% $2.95 PER I.H.P.
D.C. PART $2.25 PER I.H.P.
ARC DYN.
ARC S.B.
480 PER HR.
TRUE WATTS
620
571
549
483
461
450
LINE EFF. 96% $57.50 PER LAMP
TOTAL POWER PER LAMP = 620 WATTS = .830 I.H.P.
480 WATT ENCLOSED D.C. ARC LAMP 97% EFF. $16 PER LAMP
TOTAL POWER PER NOMINAL C.P. = .000524 I.H.P.

FIG. 7. 1150 Nominal c. p.

From the above ratios it will be seen that if 1200 c. p. is a fair nominal value for a 300-watt open arc, the enclosed D. C. might be called 900. A 300-watt A. C. enclosed would be approximately 675, and a 400-watt increased in the ratio of the watts would give 900. The candle power would undoubtedly increase more than in the ratio of the watts, and 950 has been taken as a mean value


DIRECT CURRENT BELTED OPEN ARC 430 WATT.
TOTAL COST PER LAMP
REAL ESTATE... $ 2.70
BUILDINGS..... 6.10
BOILERS ETC.... 20.80
ENGINES..... 16.65
TRANSMISSION.... 3.30
ARC DYNS..... 18.35
ARC S.B..... .20
LINE..... 57.50
LAMP..... 13.00
$ 142.60
TOTAL PER NOMINAL C.P. = $.0713
COST PER LAMP PER YEAR OF 3800 HRS.
COAL & WATER..... $ 18.30
WAGES..... 11.70
SUPT. & OFFICE..... 2.00
INT. TAXES INS. 7% 13%..... 18.50
DEPRECIATION 6%
EXTRA DEP. ACT. ARC DYN. 4%..... .73
" " " LAMP 4%..... .80
REPAIRS RENEWALS & SUPPLIES AT $ 250 PER I.H.P. 2.08
EXTRA REPAIRS ARC DYN. AT $ 250 PER I.H.P. ... .42
TRIMMING LAMPS DAILY 11.00
CARBONS..... 7.50
GLOBES..... .70
TOTAL OPERATING EXPENSES... $ 68.53
OPER. EXP. PER. NOM. C.P. = $.034+
OFFICE, STORE ROOM, SHOP, LAMP ROOM, ETC.
REAL ESTATE $.30 PER SQ.FT. = $3.23 PER I.H.P.
BUILDING $1.50 " " " = $9.73 " I.H.P.
D.C. PART OF PLANT 1.5 SQ.FT. PER I.H.P.
BOILERS, STACKS, PUMPS, CONDENSERS, PIPING, ETC.
$ 25 PER I.H.P.
TRANSMISSION 3.2 H.P. PER H.P. $ 1.03 PER H.P.
ENGINES 16.2 H.P. PER H.P. $ 1.03 PER H.P.
ARC S.B.
40 ARC K.W.
TRUE WATTS
620
571
548
483
464
430
LINE EFF. 96%
$ 57.50 PER LAMP
TOTAL POWER PER LAMP = 620 WATTS = .830 I.H.P.
TOTAL POWER PER NOMINAL C.P. = .000943
1/47
480 WATT OPEN ARC. D.C. ARC LAMP 92% EFF. $.15 PER LAMP

1864-8

FIG. 8. 2000 Nominal c. p.

in working up from the 1200 c. p. open, and down from the 2000 c. p. open D. C. The resulting costs have been divided by all the nominal candle powers so that the cost can be compared readily at any reasonable rating.

It is only recently that much attention has been paid to the distribution of light at different distances along the street. The alternating current lamp with its maximum illumination near the horizontal plane has advantages in this respect. To get the full benefit of this feature of the lamp, it is necessary to suspend the lamp somewhat lower than has been customary with continuous

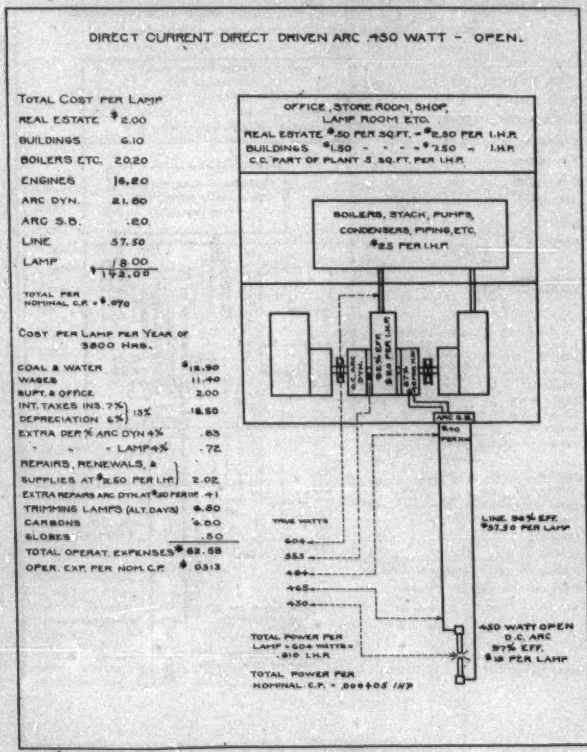
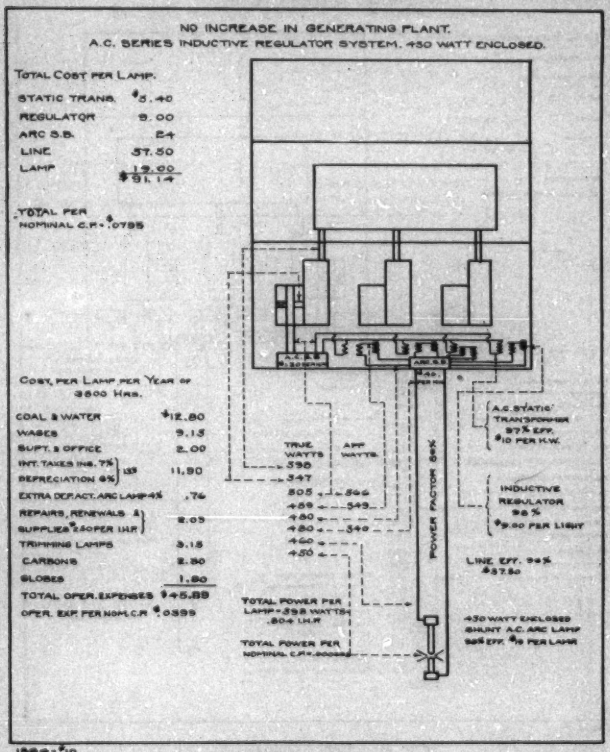

DIRECT CURRENT DIRECT DRIVEN ARC 450 WATT - OPEN.
TOTAL COST PER LAMP
REAL ESTATE $2.00
BUILDINGS 6.10
BOILERS ETC. 20.20
ENGINES 16.20
ARC DYN. 21.60
ARC S.B. .20
LINE 57.50
LAMP 18.00
$142.00
TOTAL PER NOMINAL C.P. = $.070
COST PER LAMP PER YEAR OF 3800 HRS.
COAL & WATER $12.90
WAGES 11.40
SUPT. & OFFICE 2.00
INT. TAXES INS. 7% DEPRECIATION 6% 13% 18.50
EXTRA PER % ARC DYN 4% .83
" " " LAMP 4% .72
REPAIRS, RENEWALS, & SUPPLIES AT $2.50 PER I.H.P. 2.02
EXTRA REPAIRS ARC DYN. AT $50 PER H.P. .41
TRIMMING LAMPS (ALT. DAYS) 9.50
CARBONS 2.00
GLOBES .50
TOTAL OPERAT. EXPENSES $ 62.58
OPER. EXP. PER NOM. C.P. $ .0313
OFFICE, STORE ROOM, SHOP, LAMP ROOM ETC.
REAL ESTATE $.50 PER SQ.FT. = $2.50 PER I.H.P.
BUILDINGS $1.50 " " " = $7.50 " I.H.P.
C.C. PART OF PLANT .5 SQ.FT. PER I.H.P.
BOILERS, STACK, PUMPS, CONDENSERS, PIPING, ETC. $25 PER I.H.P.
ARC S.B. $40 PER H.P.
TRUE WATTS
604
553
484
465
450
LINE 90% EFF. $57.50 PER LAMP
450 WATT OPEN D.C. ARC 92% EFF. $18 PER LAMP
TOTAL POWER PER LAMP = 604 WATTS = .810 I.H.P.
TOTAL POWER PER NOMINAL C.P. = .000+05 I.H.P.

FIG. 9. 2000 Nominal c. p.

current lamps. This brings out a feature which is worthy of consideration, namely, the effect of the direct rays on the eyes of the pedestrian or observer. For example, assuming that the illumination of objects from two lamps was equal when the observer was looking in the opposite direction from the lamp;

suppose that one of the lamps was placed quite high and the other nearly in his line of vision when looking towards the lamp; it is quite evident that whereas the illumination of objects is equal, the perceptive power of the pedestrian is decidedly impaired by the glare of the low hung lamp and he is not only less able to



1884 - $10.

FIG. 10. 1150 Nominal c. p.

perceive his surroundings but would also be considerably annoyed if the lowering of the lamp were carried to extremes.

It is also in order to call attention to the fact that if it is allowable to use reflectors to save the upper hemisphere of light in the alternating lamp, the direct current lamp should have the privi-

lege of using reflectors or other devices to reflect some of the maximum rays so as to throw them in a horizontal plane, if that is the direction in which illumination is desired. Some of the globes in present use have considerable of this effect.

Another factor in this comparison is that of color, the alterna-

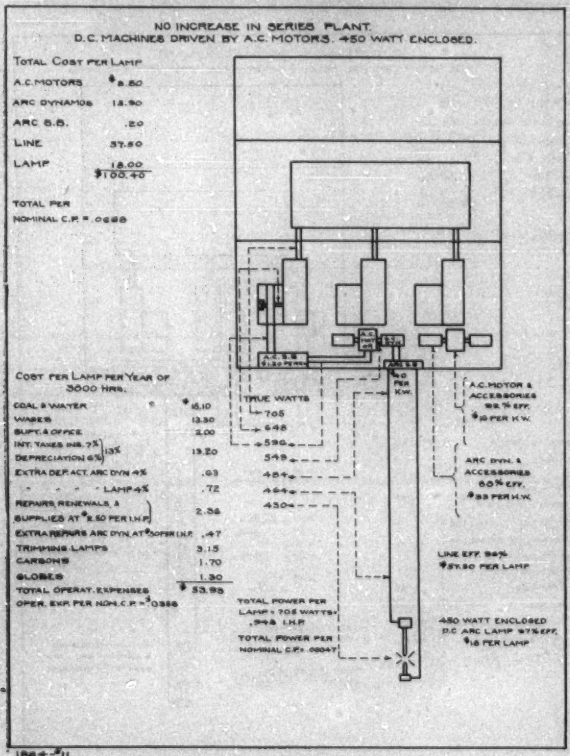

NO INCREASE IN SERIES PLANT.
D.C. MACHINES DRIVEN BY A.C. MOTORS. 450 WATT ENCLOSED.
TOTAL COST PER LAMP
A.C. MOTORS $ 8.80
ARC DYNAMOS 18.90
ARC S.B. .20
LINE 37.50
LAMP 18.00
$100.40
TOTAL PER NOMINAL C.P. = .0688
COST PER LAMP PER YEAR OF 3000 HRS.
COAL & WATER $ 15.10
WAGES 13.30
SUPT. & OFFICE 2.00
INT. TAXES INS. 7% 13%
DEPRECIATION 6% 13.20
EXTRA DEP. ACT. ARC DYN 4% .93
" " " LAMP 4% .72
REPAIRS, RENEWALS, & SUPPLIES AT $ 2.50 PER I.H.P. 2.36
EXTRA REPAIRS ARC DYN. AT $ 50 PER I.H.P. .47
TRIMMING LAMPS 3.15
CARBONS 1.70
GLOBES 1.30
TOTAL OPERAT. EXPENSES $ 53.95
OPER. EXP. PER NOM. C.P. = .0359
TRUE WATTS
705
648
590
549
484
464
430
TOTAL POWER PER LAMP = 705 WATTS = .948 I.H.P.
TOTAL POWER PER NOMINAL C.P. = .0847
A.C. 2200 VOLTS
D.C. 550 VOLTS
$ 0 PER K.W.
A.C. MOTOR & ACCESSORIES 93% EFF. $ 20 PER K.W.
ARC DYN. & ACCESSORIES 80% EFF. $ 33 PER K.W.
LINE EFF. 94% $ 37.50 PER LAMP
450 WATT ENCLOSED D.C. ARC LAMP 97% EFF. $ 18 PER LAMP
1864-11

FIG. 11. 1500 Nominal c. p.

ting lamps generally having a larger amount of violet rays. Under certain circumstances this would be an objection, and it should also be noted in this connection that photographic studies of the relative illuminating powers of arc lamps are liable to be very greatly in error on account of the superior actinic value of the violet rays.

The tables are all made out assuming that the arc lighting part of the plant to be running at very nearly full load whenever it does run. This will, of course, not apply to commercial lighting circuits, and considerable corrections will have to be made for such conditions. The following points might be mentioned in this connection.

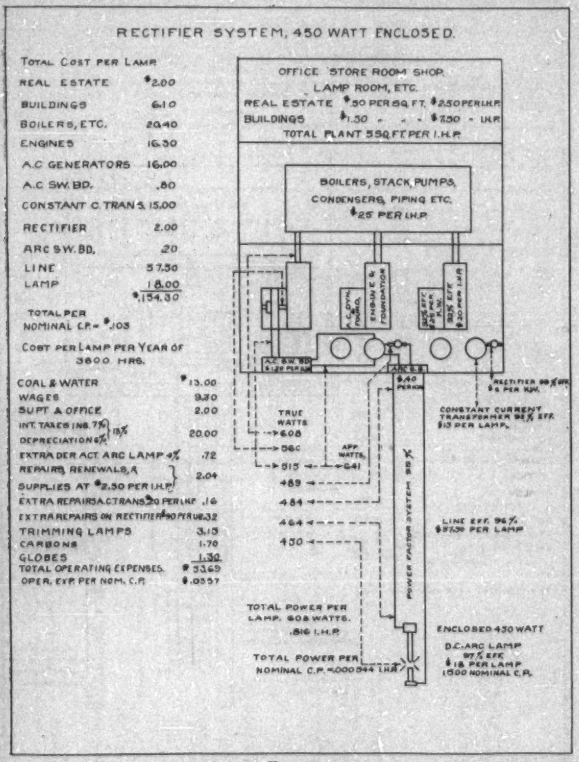

RECTIFIER SYSTEM, 450 WATT ENCLOSED.
TOTAL COST PER LAMP
REAL ESTATE $2.00
BUILDINGS 6.10
BOILERS, ETC. 20.40
ENGINES 16.30
A.C. GENERATORS 16.00
A.C. SW. BD. .80
CONSTANT C. TRANS. 15.00
RECTIFIER 2.00
ARC SW. BD. .20
LINE 57.30
LAMP 18.00
$154.30
TOTAL PER NOMINAL C.P. = $.103
COST PER LAMP PER YEAR OF 3800 HRS.
COAL & WATER $13.00
WAGES 9.30
SUPT. & OFFICE 2.00
INT. TAXES INS. 7%
DEPRECIATION 10% 20.00
EXTRA DEP. ACT. ARC LAMP 4% .72
REPAIRS, RENEWALS, & SUPPLIES AT $2.50 PER I.H.P. 2.04
EXTRA REPAIRS A.C. TRANS. $.20 PER I.H.P. .16
EXTRA REPAIRS ON RECTIFIER $.30 PER I.H.P. .32
TRIMMING LAMPS 3.15
CARBONS 1.70
GLOBES 1.30
TOTAL OPERATING EXPENSES. $ 53.69
OPER. EXP. PER NOM. C.P. $.0337
OFFICE STORE ROOM SHOP LAMP ROOM, ETC.
REAL ESTATE $30 PER SQ. FT. $.250 PER I.H.P.
BUILDINGS $1.50 - - - $.750 - I.H.P.
TOTAL PLANT 3 SQ. FT. PER I.H.P.
BOILERS, STACK, PUMPS, CONDENSERS, PIPING ETC. $25 PER I.H.P.
A.C. GEN. PANEL, ENGINE & FOUNDATION
A.C. SW. BD. $.80 PER I.H.P.
A.C. SW. BD. $.20 PER LAMP
ARC S.B.
$.40 PER KW
RECTIFIER 98% EFF. $6 PER KW.
CONSTANT CURRENT TRANSFORMER 94% EFF. $10 PER LAMP.
TRUE WATTS
608
APP. WATTS.
641
515
489
484
464
450
POWER FACTOR SYSTEM 80%
LINE EFF. 96% $.539 PER LAMP
TOTAL POWER PER LAMP. 608 WATTS. .816 I.H.P.
TOTAL POWER PER NOMINAL C.P. = .000344 I.H.P.
ENCLOSED 450 WATT D.C. ARC LAMP 97.5% EFF. $18 PER LAMP 1500 NOMINAL C.P.

FIG. 12.

The continuous current generators will fall off quite rapidly in efficiency as the load goes down. The engine efficiency will also fall off in the case where the machines are operated directly from the engines until the load is sufficiently reduced to permit shut-

ting down one of the engine units. Some A. C. systems have the disadvantage that it is not practicable to operate them at all on very light loads, but the efficiency is not very greatly reduced at light load although the decrease in efficiency of the system is augmented by the fact that the power factor runs to quite low values at the light loads.

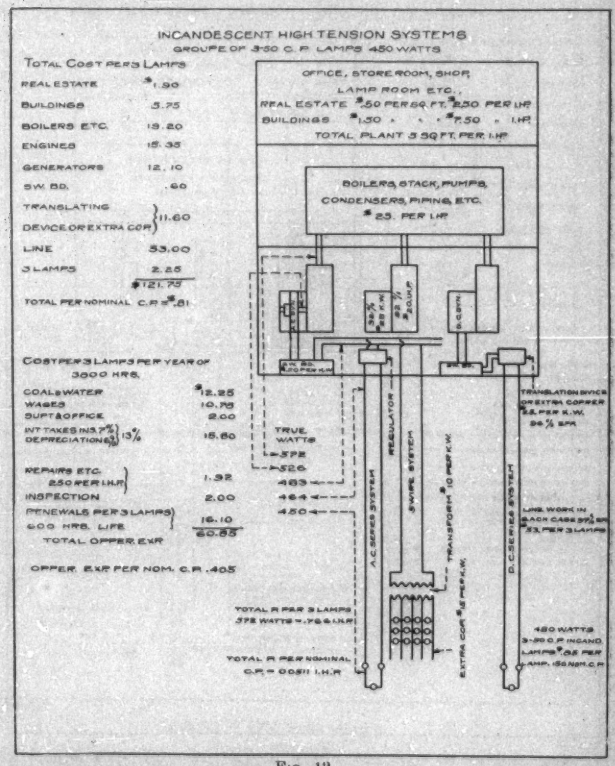

INCANDESCENT HIGH TENSION SYSTEMS
GROUPS OF 3-50 C. P. LAMPS 450 WATTS
TOTAL COST PER 3 LAMPS
REAL ESTATE $1.90
BUILDINGS 5.75
BOILERS ETC. 19.20
ENGINES 15.35
GENERATORS 12.10
SW. BD. .60
TRANSLATING DEVICE OR EXTRA COR. 11.60
LINE 53.00
3 LAMPS 2.25
$121.75
TOTAL PER NOMINAL C.P. = $.81
COST PER 3 LAMPS PER YEAR OF 3000 HRS.
COAL & WATER $12.25
WAGES 10.75
SUPT & OFFICE 2.00
INT. TAXES INS. 7% DEPRECIATION 6% 13% 15.60
REPAIRS ETC. 2.50 PER I.H.P. 1.32
INSPECTION 2.00
RENEWALS PER 3 LAMPS 600 HRS. LIFE 16.10
TOTAL OPPER. EXP. 60.85
OPPER. EXP PER NOM. C.P. .405
OFFICE, STORE ROOM, SHOP, LAMP ROOM ETC.,
REAL ESTATE $.50 PER SQ. FT. $250 PER I.H.P.
BUILDINGS $1.50 " " $7.50 " I.H.P.
TOTAL PLANT 3 SQ. FT. PER I.H.P.
BOILERS, STACK, PUMPS, CONDENSERS, PIPING, ETC.
$25. PER I.H.P.
ENGINES
GENERATORS
SW. BD.
TRUE WATTS
525
525
483
464
450
A.C. SERIES SYSTEM
REGULATOR
SHUNT SYSTEM
TRANSFORM $10 PER K.W.
D. C. SERIES SYSTEM
TRANSLATION DEVICE OR EXTRA COPPER $5. PER K.W. 96% EFF.
LINE WORK IN BACK CASE $53. PER 3 LAMPS
TOTAL P PER 3 LAMPS 375 WATTS = .75 I.H.P.
TOTAL P PER NOMINAL C.P. = .0011 I.H.P.
EXTRA COR. $5 PER K.W.
480 WATTS 3-50 C.P. INCAND. LAMPS $.85 PER LAMP. 150 NOM. C.P.

FIG. 13.

Another point in favor of the alternating systems is the fact that the location of the plant or other local conditions, may permit a saving in the line investment, for example, where a large number of circuits had to be run for a long distance in the same

TABLE A.

COST PER LAMP PER YEAR OF 3800 HOURS.	Hartford 400 watt enclosed.	Hartford 450 watt enclosed	Alt. C. Ind. Reg. 400 watt enclosed.	D.C. Arc driven by A. C. motors 300 watt enclosed.	D.C. Arc belted 300 watt enclosed.	D.C. Arc driven by D. C. Motors 300 watt enclosed.	D.C. Arc belted 450 watt enclosed.	D.C. Arc belted 450 watt open arc.	D.C. Arc direct driven 450 watt open D.C.	Alt. C. Ind. Reg. 450 watt enclosed. No incr. gen. plant.	D.C. Arc driven by A. C. motors 450 watt enclosed. No incr. gen. plant	Rectifier System. 450 watt enclosed.	Incand 3-50 C. P. Lamps 450 watts
	1	2	3	4	5	6	7	8	9	10	11	12	13
Total cost per lamp	146.50	155.24	139.80	131.42	117.90	129.45	147.37	142 60	142.00	91.14	100.40	154.30	121.75
Total cost per nominal C. P.	.154	.1349	.147	.146	.131	.144	.0082	.0713	.071	.0795	.0669	.103	.81
I. H. P. per Lamp	.744	.822	.708	.630	.552	.642	.830	.832	.810	.804	.948	.816	.766
I. H. P. per Nominal C. P.	.000785	.000715	.000744	.000700	.000614	.000714	.000554	.000415	.000405	.000698	.000631	.00544	.00511
OPERATING EXPENSES.													
1. Coal and water	11.85	13.10	11.30	10.05	8.80	10.20	13.25	13.30	12.90	12.80	15.10	13.00	12.25
2. Wages	8.50	9.35	8.07	8.85	7.78	9.00	11.68	11.70	11.40	9.15	13.30	9.30	10.78
3. Supt. Office, etc.	2.00	2.00	2.00	2.00	2 00	2.00	2,00	2.00	2.00	2.00	2.00	2,00	2.00
4. Int. Taxes, Ins, 7 per cent. Depreciation, 6 per cent. } 13 per cent.	19.00	20.20	18.15	17.10	15.30	16.80	19.10	18.50	18.50	11.90	13.80	20.00	15.80
5. Extra Deprec. Arc. Dyn.				.42	.49	.42	.68	.73	.83		.63		
6. Extra Deprec. Arc Lamps	.80	.80	.76	.72	.72	.72	.72	.60	.72	.76	.72	.77	
7. Repairs, Renewals, Supplies	1.86	2.26	1.77	1.57	1.38	1 60	2.07	2.08	2.02	2.03	2.36	3.04	1.92
8. Extra Repairs Arc Dyn.				.32	.28	.32	.42	.42	.41		.47		
9. Extra Repairs, Const. C. Transf.	.15	.18										.48	
								DAILY.	ALT.DAYS				INSPECT'N
10. Trimming	5.20	5.86	5.20	2.60	2.60	2.60	3.15	11.00	6.50	3.15	3.15	3.15	2.00
11. Carbons	1.90	2.30	1.90	1.40	1.40	1.40	1.70	7.50	6.80	2.30	1.70	1.70	RENEWALS
12. Globes	1.60	1.80	1.60	1.00	1.00	1.00	1.30	.70	.50	1.80	1.30	1.30	16.10
Total operating expenses	52.86	57.85	50.75	46.03	41.75	46.06	56.07	68.53	62.58	45.89	53.93	53.69	60.85
Operating expenses at 2000 C. P.	.0264	.0289	.0289	.0235	.02087	.0231	.0280	**.0342**	**.0313**	.0230	.0269		
" " " rated at 1500 C. P.	.0353	.0385	.0338	.0306	.0278	.0307	**.0375**	.0457	.0417	.0306	**.0359**	**.0357**	
" " " 1200 C. P.	.0441	.0482	.0423	.0375	.0348	.0386	.0467	.0572	.0521	.0382	.0448		
" " " 1150 C. P.	.0460	**.0503**	.0442	.0402	.0363	.0401	.0490	.0595	.0544	**.0399**	.0468		
" " " 950 C. P.	**.0557**	.0608	**.0535**	.0484	.0440	.0484	.0591	.0720	.0656	.0484	.0568		
" " " 900 C. P.	.0588	.0644	.0563	**.0512**	**.0464**	**.0513**	.0624	.0760	.0695	.0539	.0599		
" " " 150 C. P.													**.405**

street, a saving in the investment could probably be made by the alternating system by the use of a sub-station at the point of distribution. The extra attendance and cost of the sub station would, in most cases, partially offset the advantage. Where the extra load would not interfere, the mains already in use might also be used for an alternating system.

In cases where there is already a greater generator capacity installed than is actually needed, it is, of course, possible to leave out a considerable portion of the investment shown in the tables. This would apply to any of the motor-driven direct-current systems as well as the A. C. systems. See Figures 10 and 11.

In rare cases, the peak of the commercial lighting and power load would not overlap the arc lighting load, and under such circumstances, some of the transformer systems, either direct or alternating current would have a great advantage.

Explanation of Tables.

The plants shown in the tables are, of course, intended only as diagrammatic representations of the conditions, and not as actual arrangements best suited for the purpose.

The tables are on what might be considered a minimum basis, that is, there is no allowance made for reserve in buildings or real estate, nor is there any allowance for reserve in the generating plant beyond the fact that the engine and dynamo units have been so subdivided as to avoid a great percentage of shut-down in case of accident. The cost of line has been reduced, and in fact all other items in the different plans have been reduced to what might be considered a minimum for a first-class plant. The alternating plants shown, have a slight advantage in the freedom from shut down over the engine driven, direct-current plants, although in the latter the engine unit is sub-divided and an extra allowance is made for this and for arranging one engine to carry the greater part of the load in the case of accident to the other unit. In the case of Fig. 9 where the Arnold system is suggested, the direct current plant is not open to this objection, and for that matter, any of the plants could be arranged in this way without very great increase in cost.

No plans showing the ordinary low-tension constant potential A. C. arc system, have been put in, as the economy is so poor when compared with the series systems except when the system approximates the conditions shown in Fig. 3.

Figure 13 is intended to give a rough idea of the operating expenses of several kinds of incandescent lighting systems.

The diagram on the left might represent a series incandescent system with an inductive regulator in the station, or, it could represents a constant current transformer system.

The diagram in the middle is intended to represent a constant potential system of distribution which in some cases would have

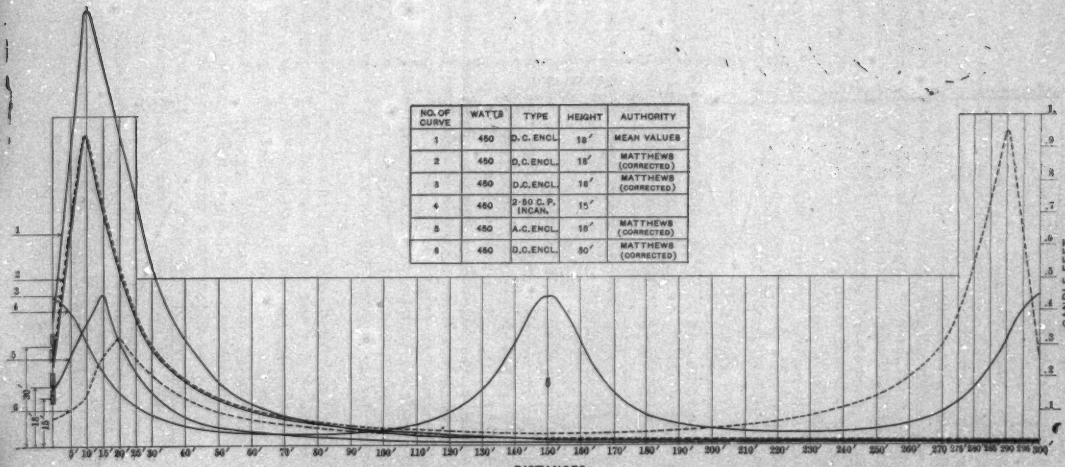

NO. OF CURVE | WATTS | TYPE | HEIGHT | AUTHORITY
1 | 450 | D.C. ENCL. | 18′ | MEAN VALUES
2 | 450 | D.C. ENCL. | 18′ | MATTHEWS (CORRECTED)
3 | 450 | D.C. ENCL. | 18′ | MATTHEWS (CORRECTED)
4 | 450 | 2-80 C. P. INCAN. | 15′ |
5 | 450 | A.C. ENCL. | 18′ | MATTHEWS (CORRECTED)
6 | 450 | D.C. ENCL. | 30′ | MATTHEWS (CORRECTED)
CANDLE FEET
DISTANCES

FIG. 14. Curves showing, Luminous Intensity at Street Surface with Different Lamps.

CANDLE FEET
DISTANCES
CURVE | WATTS | TYPE | HEIGHT | AUTHORITY
1 | 450 | D.C | 30' | MEAN VALUE
2 | 450 | INC. L. | 15' |
3 | 450 | A.C. | 80' | MATTHEWS (CORRECTED)
4 | 450 | D.C. | 30' | MEAN VALUES

FIG. 15 Curves showing Luminous Intensity at Street Surface with Different Lamps.

the advantage of utilizing some of the mains already in place for other work. The lamps are shown in series multiple but, of course, could just as well be in plain series or multiple arrangements.

The diagram on the right side might be taken to represent a number of direct current series systems. For example, a small dynamotor might be used where it was desired to run at a higher voltage than that of the station, and where no great amount of regulation was required. If considerable regulation was needed a double field motor generator might be used, the potential being regulated by the secondary machine. Machines like constant current arc machines could be used for this purpose. They could of course, be given much higher efficiency than arc machines, as they do not have to give the stability to the current which is necessary for running constant current arc lamps. This could even be extended to quite large machines of the multi-circuit type if there was any great amount of such lighting to be done.

Value of Items in Tables.

Real estate has been taken at 50 cents per square foot as representing a fair average value, the actual values ranging anywhere from nothing to seven or eight dollars per square foot.

Buildings have been taken at one dollar and a half per square foot, the range in this respect being nearly as great as for real estate.

Boilers, foundations, stacks, pumps, condensers, piping and other accessories have been lumped together at $25 per indicated H. P. We have figures on plants where this item runs as low as nine dollars and as high as $40 per I. H. P. of engine. This item has been increased to $27 per I. H. P. in the engine-driven D. C. arc plants to allow for extra accessories on account of subdividing the units. The engine and boiler items are, of course, inter-dependent as, when engines are cheap, the tendency is for an increased cost of the boiler plant. The attempt has been made to get an average current market value for all classes of boilers and engines.

Engines and foundations have been figured at $20 per I. H. P. This figure will run as low as $10, per I. H. P. and as high as $50 per I. H. P. for high-class triple expansion verticals. The rate has been increased to $22. per I. H. P. on some of the engine-driven plants, to allow for greater subdivision, etc.

A. C. generators and foundations have been taken at $25 per K. W. as a fair value of what would be put in a modern plant. These figures vary from $12 to $35 per K. W.

D. C. arc generators vary in price from less than $30 to $45 per K. W.

The belted arc machines have been taken at $35 per K. W. and the higher speed motor-driven machines at $33 per K. W. Large direct-driven machines would average about $45.

A. C. constant current transformers have been taken at $15 per lamp for both 400 and 450 watt lamps as there is considerable variation in the accessories to these transformers.

A. C. inductive regulators have been taken at $9.00 per lamp. This can be made a very variable item on account of the amount of regulation to be provided for as well as other reasons. The figure is intended to cover a regulator to control the entire circuit.

The line has been figured at $51.10 per lamp for the 300-watt enclosed D. C. lamp. This figure was based on the use of hard-drawn copper wire with weather-proof covering and the ordinary pole and suspension construction such as would be used in small towns or the outlying districts of cities. The size of wire for the other systems has been increased as nearly as possible in the ratio of the current, the other conditions remaining the same.

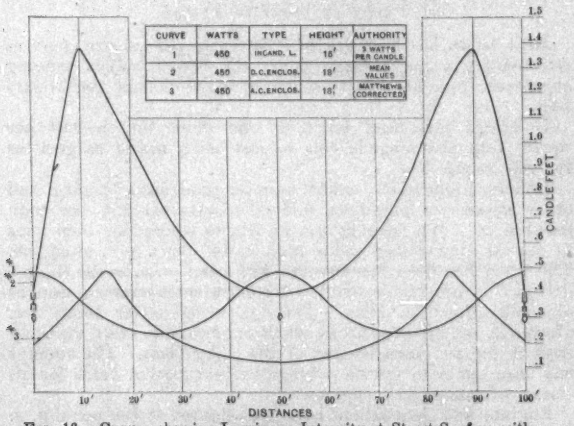


FIG. 16. Curves showing Luminous Intensity at Street Surface with Different Lamps.

It will be noted that an increase in the cost of this line construction will add a fixed amount to the investment and operating expenses, and will not affect the absolute differences between the systems. The percentage difference will vary, however.

The line and pole work such as is used in large cities will run from $100 to $150 per lamp, while underground cables and conduits will run from $200 to $300 per lamp.

The other smaller items will be found on the plans.

In the rectifier system shown in Fig. 12, the values of the items have been taken from corresponding parts of the other

tables and the rectifying commutator has been put in at $2.00 per K. W. in the absence of definite figures on the subject. It might be mentioned here that there seems no immediate prospect of commercial rectifiers of good-sized units except on very low frequencies.

The incandescent systems shown in Fig. 13 have been put in to afford a rough comparision with the arc systems. The corresponding items have been placed at the same values as in the arc tables. The lamps have been assumed to be 50 c. p. lamps at an average cost of 85 cents per lamp, and having an efficiency of 3 watts per candle and an average life of 600 hours. It seems probable that these figures could be improved upon if such systems came into very general use.

Operating Expenses.

Coal and water have been figured at .42 of a cent per I. H. P. hour. This figure was obtained by averaging the average values given by Foster and Moses in their papers before the Institute, the values given in the *Street Railway Journal* and from a number of arc lighting plants on which we had figures. The values vary from .28 of a cent per I. H. P. to .76. .42 of a cent per I. H. P. hour corresponds with .7 of a cent per K. W. hour with 80 per cent combined efficiency for engine and dynamo.

Wages have been figured at .15 of a cent per I. H. P. hour in the boiler room; the same in an alternating current dynamo and engine room, and at .22 of a cent in the arc dynamo room.

The superintendence and office expenses have been figured at $2.00 per year per lamp in all cases, as this will not vary materially with the kind of plant used.

Interest, taxes and insurance are figured at 7%; depreciation at 6%; this depreciation factor might more strictly be called replacement, as it is intended to include not only real depreciation, but also a factor for replacing machinery caused by competition with improvements.

A sum at compound interest at 6% would equal the original in eleven and one-half years, so that this would seem to be large enough.

Extra depreciation on arc dynamos and arc lamps has been placed at 4%. This makes a total of 10% for the replacement factor on these portions of the plant. This would cover complete replacement in a little over seven years.

The general repairs, renewals and supplies have been taken at .07 of a cent per I. H. P. hour. Extra repairs on arc dynamos have been taken at .015 per I. H. P. hour. It might be remarked that in several modern arc plants, of which the figures are at hand, this value is considerably less.

Extra repairs on A. C. constant current transformers has been placed at .007.

The figures for trimming arc lamps have been taken from the data of the plants at hand. In all cases we have figures a little more or less than half the values used. In some cases the cost for trimming runs up nearly double the values taken. For example, we have figures varying from $1.00 to $6.25 per lamp per year for direct current enclosed lamps of 400 to 450 watts. The difference comes mainly in the time spent in cleaning the inner globes and in the price of labor as well as the number of lamps taken care of by a man. The figures on enclosed lamps are such as would allow the globes to be kept fairly clean, and the cost of trimming alternating enclosed lamps has been increased by a small factor on account of the practice which obtains in some stations of cleaning the globes of these lamps oftener than the direct current lamps under the same conditions.

The alternating lamps consume their carbons faster than direct current lamps partly on account of the increased wattage and partly on account of the almost universal practice of using one cored carbon. The use of the cored carbon also materially increases the blackening of the globe. In Figure 10 the 450-watt alternating lamp is assumed to have solid carbons, and has the same cost for trimming as the D. C 450 watt lamp.

The cost for globes was taken in the same way as the trimming cost.

The life of incandescent lamps has been taken at 600 hours and the cost of the lamps at 85 cents. An allowance of $2.00 a year per each three lamps has been made for inspection and cleaning.

Curves of Illumination.

The illuminating values of different lamps depend quite as much on their location as upon the system of operation.

A number of curves have been plotted to show the illumination of the various types of lamps under different conditions.

The ordinates of the curves represent the illumination at various distances from the foot of the lamp-post.

It has been thought that for street lighting purposes, it was fairer to take as illuminating values the illumination on a plane normal to the ray of light in each case, rather than the values sometimes used which represent the illumination on the plane of the street and are the normal values multiplied by the sine of the angle between the ray of light and the horizontal. If the sine values had been used the results would, of course, have been much lower in value and the high lamps and the lamps nearer together would have a still greater advantage than what the curves show. It is probable that the useful effect is somewhere between the normal and sine values but nearer the normal.

In all cases no reflectors have been used, and no allowance has been made for the upper hemisphere of light. There is no doubt but that the light in the upper hemisphere is of considerable value, even without the use of reflectors, as the illumination

of surrounding buildings and trees saves a considerable percentage of the upper hemisphere of light, especially in wet weather. It will be noted in this connection that the incandescent and alternating arc lamps would both be quite materially improved if some allowance could be made for the upper hemisphere.

Figure 14 is a comparison of different arc lamps hung 300 feet apart and incandescent lamps 150 feet apart.

Curve 1 represents the illumination from a direct current enclosed arc of 450 watts.

The candle-power curve for this lamp was obtained by averaging the curves given by the following experimenters:

Matthews, Thompson and Hilbish, INSTITUTE Paper Opalescent inner globe	384 watts at arc.
Freedman, Burroughs and Rapaport, INSTITUTE Paper. Opalescent inner, no outer globe	410 " " "
Marks, Chicago Electrical Congress. Thin opal inner and clear outer globe	504 " " "

In each case the curves were increased or diminished in the ratio of the watts to reduce them to 450. The illumination would, of course, not vary in direct ratio with the watts, but it was thought that the error introduced in this way would be small compared with the great discrepancies introduced by other factors.

Curves showing the variation of the efficiency with different values of arc wattage appear to have maximum values depending on a great many conditions, and it was not thought worth while to attempt to assume any factors for correcting the curves other than in the direct ratio of the wattage. It is lamentable that there have not been more curves published, giving full information, and that we have to fall back on such methods as the above if we do not care to work from the results of individual experiment.

Curve 1 shows the light from one such average lamp hung 18 feet high.

Curve 2 is plotted from the results of Matthews *et al* used in making the above average. This was used as more information was given with the curve. Lamp hung 18 feet above street.

Curve 3 is the same as Curve 2 except that the illumination from two lamps 300 feet apart is considered, the result being the summation of two curves like Curve 2.

Curve 4 represents the illumination from six 50 c. p. incandescent lamps in clusters of two, on posts 150 feet apart, 15 feet above the street. The illumination from these lamps was assumed to be a hemisphere of 100 c. p. in radius. No reflector was used, and no allowance made for upper hemisphere. At three watts per candle these six lamps would consume 900 watts, which is the same power as given to the two arc lamps.

Curve 5 is for an alternating enclosed lamp with opalescent inner globe, taking 327 watts at the arc, as given by Matthews *et al*. No

reflector was used. The candle power distribution curve of the lamp was corrected in the ratio of 450 to 327 watts. It is regretable that no better curve for the alternating lamp was at hand for the purpose, as it undoubtedly does not show the alternating lamp to full advantage.

It will be noted that in the discussion of Mr. Matthews' paper, Mr. Marks thought that the D. C. lamp would be less than 35% better in efficiency than the A. C. lamp taken, whereas the paper gives more than 50% better efficiency for the D. C. lamp. Mr. Matthews, in a recent letter, has also stated that he thought this value should be reduced to something less than 35% so that it is fair to assume that the illumination curve from the A. C. lamp should be raised about 20% through all the curves.

Curve 6 is the same as Curve 2 except that the lamp has been raised from 18 to 30 feet high. It will be noticed that the street illumination is less near the lamp, but begins to be greater at distances over 140 feet. At 300 feet the high lamp gives about one-third more illumination. The mean ordinates come out as follows:

2-D. C.	encl.	18 ft. high,	300 ft. apart,	mean results, ...	.34
"	"	"	"	Matthew *et al*	.18
"	"	30 ft. "	"	"	.059
2-A. C.	"	18 ft. "	"	"	.051

6-50 c. p. incandescent, bunches of 2, 150 ft. apart. 15 ft. high, .14

It will be noted that the mean illumination from the incandescent lamps is considerably higher than any but the direct low hung lamps. The minimum ordinate of Curve 3 is .034, that of Curve 4 is also .034.

Figure 15. The curves on this plate shows the relative illuminations with a 600-foot distance for the arc lamps.

Curve 1 is the D. C. enclosed lamp from mean results as in Curve 1 of Fig. 14. The lamps are placed 30 feet high.

Curve 2 represents the illumination from seven 50 c. p. incandescent lamps 100 feet apart, 15 feet high. 2.6 watts[1] per candle.

Curve 3 is for the alternating lamp as in Curve 5, Fig. 14, except that it is hung 30 ft. high.

Curve 4 is the illumination from two of the lamps of Curve 1, 600 feet apart.

The value of the mean ordinate for the two D. C. enclosed lamps is .10 The mean ordinate for two alternating lamps would be .036. The mean ordinate for the incandescent lamps is .11 The minimum ordinate of Curve 2 is .037, that of Curve 4 is .007.

It will be seen that the relative effectiveness of the incandescent lamps increases quite materially with the distance be-

1. This efficiency could be obtained easily by the use of reflectors, or we might even hope to reach this result with the lamps themselves, if there were very large demands for such systems.

tween arc lamps, and that at greater distances between arc lamps the incandescent system would give a much better mean illumination.

Figure 16. This is a comparison of the lighting at short distances such as would occur in the business district of a city.

Curve 1 is the illumination from six 50-c. p. incandescent lamps, taking a total of 900 watts located in clusters of two, 50 feet apart. Height above street, 15 feet.

Curve 2 gives the illumination from two of the mean D. C. enclosed lamps taken for Curves 1 in the other plates. The lamps are 100 feet apart and 18 feet high.

Curve 3 is for two A. C. enclosed lamps as in the other plates, 18 feet high.

The mean ordinates are .35 for the incandescent lamps, .76 for the D. C. enclosed lamps and .28 for the A. C. enclosed lamps. The relatively poor showing of the A. C. lamps in this case is partly due to the low efficiency of the lamp as discussed previously, and partially to the fact that its light is more concentrated near the horizontal plane. Reflectors on the lamps and reflection from buildings would bring up the utility of the A. C. lamp considerably.

Conclusion.

A perusal of Table A, which gives a summary of the different systems, makes it evident that open D. C. arc lamps show up quite well as compared with more recent improvements when only the quantity of light is taken into consideration. It must be borne in mind that to get these results for open arcs the most modern apparatus has been taken in the station, and the operating expenses are also reduced to the best average modern practice. It is perhaps not fair to compare the open and enclosed lamps without any consideration of the quality of the light, so that we will have to discount the results for open arc lamps, depending a great deal upon individual opinion.

The alternating arcs do not show very favorably in making the various comparisons. The principal loss comes from the relative inefficiency of the arc itself. If this can be improved upon, or if the ratio taken between the D. C. and A. C. arc can be brought down, the relative economy of the A. C. systems would increase quite rapidly.

In general it will be seen that the D. C. plants are the most favorable for places where the whole or nearly all the output is used for arc lighting. Where but a small portion of the load is arc lighting, either the straight alternating systems or some of the systems transforming into direct continuous current by means of motor generators or rectifiers would be the most practicable.

There seems to be no particular reason why large direct current lighting or railway plants should not go into the series arc lighting business more than has been the practice. It appears

that they could operate arc lights or direct current series incandescents with very good economy as far as the lighting is concerned, and probably increase the economy of operation of the rest of the plant as well. Where there are already storage batteries installed, there are a number of additional advantages resulting from the combination. In this connection it might be well to note that the ordinary direct current arc machine is perhaps the best suited of all generators to be driven at variable speed, so that there is not likely to be any great disturbance on the arc circuits caused by a fluctuation of speed or voltage in a railway plant.

The problem of building motors to run at a fairly constant speed with reasonable variations in voltage has also been taken up recently and solved with fair success.

The curves of illumination seem to show that arc lighting is by far the most economical method of lighting the central parts of cities, while in sparsely populated districts incandescent lamps seem to have a great many advantages. There is no doubt but that the very glare of an arc lamp impresses the public considerably. and that in passing from open arcs to enclosed and then to incandescents we are losing this effect and tending in the direction of Welsbach or ordinary gas lighting.

A paper presented at the 138th Meeting of the American Institute of Electrical Engineers, New York, December 27th, 1899.

AN AMERICAN PACIFIC CABLE.

BY GEORGE OWEN SQUIER.

It is interesting to note that the idea of a trans-Pacific submarine cable was first discussed and considered by the late Cyrus W. Field, nearly thirty years ago. The scheme of Mr. Field and his associates involved a route from California via Alaska and the Aleutian Islands to Japan. Since that date, the subject in some form has been almost constantly before this country and Great Britain. This question has been discussed in the fifty-second, fifty-fourth and fifty-fifth Congresses, in each of which effort was made looking towards laying a cable at least as far as the Hawaiian Islands.

In a special message to Congress, dated February 10, 1899, the President says:

"As a consequence of the ratification of the treaty of peace between the United States and Spain, and its expected ratification by the Spanish Government, the United States will come into possession of the Philippine Islands, on the farther shore of the Pacific. The Hawaiian Islands and Guam becoming United States territory, and forming convenient stopping places on the way across the sea, the necessity for speedy cable communication between the United States and all these Pacific islands has become imperative. Such communication should be established in such a way as to be wholly under the control of the United States, whether in time of peace or of war. At present the Philippines can be reached only by cables which pass through many foreign countries, and the Hawaiian Islands and Guam can only be communicated with by steamers, involving delays in each instance of at least a week. The present condition should not be allowed to continue for a moment longer than is absolutely necessary."

The idea of a British Pacific cable, connecting the Dominion of Canada with the Australasian colonies, almost from the first has been discussed from a national standpoint. Her Majesty's Government and the colonial governments most concerned, have been urged from time to time to consider the matter in its strategic and commercial aspects. Two colonial conferences, in 1887 and 1894, were largely occupied with this subject, as evidenced by the exhaustive blue books which record their proceedings. The Dominion Government took the matter up in 1893–4, and invited the most reputable firms in the world to submit estimates for construction and laying.

In 1896, Mr. Chamberlain, Secretary of State for the Colonies, appointed a Pacific Cable Commission, which included among its members the Under Secretary of State for the Colonies, the High Commissioner of Canada and the Agents-General for New South Wales and Victoria. This committee went into the whole subject of the practicability, cost, probable revenue, and management of the proposed enterprise and elicited a fund of technical, commercial, and professional information upon cable manufacture and cable laying in general, and upon this important project in particular, which is invaluable, and which probably could not have been obtained in any other manner. At this moment a Pacific cable touching only soil belonging to Great Britain is assured, both Canada and Australasia recently having been reported as joining with England in pledging themselves to the enterprise as a government undertaking.

The proposed route with surface distances involved, is shown on the accompanying map, and is from Vancouver to Fanning Island, thence to the Fiji Islands, thence to Norfolk Island, and from there bifurcating to New Zealand and Queensland.

Since a Pacific cable will at last complete the telegraphic circuit of the globe, it will give the peculiar advantage of placing each point thereon in cable connection with every other point by *two* distinct routes either east or west.

The cardinal idea in the British system has been that all state cables shall touch only British soil, and this principle has placed British cable traffic in the Pacific forever at a disadvantage over the American cable for the reason that the only available route involves a single span of cable from Vancouver to Fanning Island, over 3,500 miles in length; whereas, by the annexation of the Hawaiian Islands, the United States, while following a

similar principle, will have no span longer than the present Atlantic cables, or about 2,500 miles in length.

Since the speed of cabling decreases in general with the square of the length of the cable, and the speed of the whole system is limited by the speed of the slowest span, that system requiring the longest single span is ultimately at a disadvantage, provided the systems are in direct competition. In the projected Pacific cable enterprises, however, although, as will be pointed out later, they will operate in close relations with each other, yet each has a sufficient prospective traffic to guarantee the enterprise as a sound financial success from the beginning.

American Cable Routes.

In the consideration which, from time to time, has been given the project of spanning the Pacific ocean by a submarine cable, the Northern route, via Alaska, the Aleutian Islands, Siberia, and Japan has been frequently proposed.

In recent years the British Government, in its proposed line from Canada to Australasia, first projected this northern route owing to the absence, at that time, of information respecting the southern Pacific ocean, and the impression which prevailed that physical difficulties existed which offered insuperable obstacles to the laying of a cable on a direct route between Canada and Australasia. In consequence of this impression it was designed to lay the cable from Vancouver to Japan, touching at islands in the Aleutian and Kurile groups as mid-ocean stations. From Japan the connection with Australasia would have been obtained via Singapore and the Eastern Extension Company's lines of telegraph. Through the intervention of the government, negotiations were opened with the view of securing one of the Kurile Islands. Japan was asked to transfer to the British crown one of these islands in order that the telegraph station should be under British protection, and an agent was sent to Washington who, after some difficulty, obtained conditional landing privileges on one of the Aleutian islands

Recently there has been a revival of interest in this route, especially now that the growing commercial interests of Alaska are becoming important. The plan proposes starting from Cape Flattery, thence to Sitka, distances (approximate) 803 miles; thence to Kadiak Island, 682 miles; thence to Dutch Harbor,

770 miles; thence to Attu, 810 miles; thence to the Japan-Russian border, 858 miles, thence to the Japanese land lines, 810 miles; from the Siberian border to the Siberian lines, 617 miles; and from Formosa to Luzon, 200 miles; in all 5550 nautical miles, exclusive of the Japanese system.

It will be noticed that this series of cables aggregating 5550 miles makes no provision for American communication with the Philippines, except over the Japanese land lines from the north point of Japan to the south point of Formosa, a distance through a foreign territory of about 1200 miles. Owing to the uncertainty of the Japanese land lines, which are frequently interrupted during the typhoon season, particularly in Formosa, it would be necessary, in order to ensure communication, to extend the Japanese cable system. Again, the Great Northern Telegraph Company, a Danish corporation, has exclusive rights, not only on the Siberian coast but also between Japan and the Asiatic coast.

Apart from establishing telegraphic communication *free from foreign control* between the United States, the Hawaii Islands, the Philippine Islands and the island of Guam, the mission of an American Pacific cable should be to bring about a general reduction of cable rates.

On the Alaskan route, a large number of intermediate stations must be established and maintained; and there must be a division of receipts with Japan. A message via Honolulu, an intermediate island station and Guam, would reach Luzon by four cable transmissions. The Alaskan route as proposed would necessitate about fifteen separate stations, of which nearly one-half would be under Japanese control.

Undoubtedly an Alaskan cable will soon be required, and apparently also the extension of such a cable system as a means of attaining a through line to the Philippine Islands is an attractive plan. This plan, however, leaves the United States in practically the same unsatisfactory position she is in at present in respect to communication with her Pacific possessions, and until definite and perpetual concessions are forthcoming, can furnish even no guaranty of substantial reduction from the present high rates.

It is believed that no one studying the true present and future interests of the United states can come to any other conclusion relative to an American Pacific cable, than the one so admirably

expressed by the President in his special message to Congress, *viz.* that this cable shall be "wholly under control of the United States."

This cardinal idea—the principle also adopted by Great Britain, after years of exhaustive consideration—at once excludes the northern route for the present, and limits the route to American territory.

Practicability.

There is no longer any doubt as to the practicability of the Pacific cable project from a technical and engineering point of view. A preliminary survey between the coast of California and the Hawaiian Islands was completed by the Navy department in 1892,[1] showing the entire practicability of this part of the route. Between California and the Hawaiian Islands several approximately parallel routes are practicable, but the one which seems to be favored by the survey of 1892, as shown in the report of the Hydrographic office of the Bureau of Navigation, is a rhumb-line between Monterey Bay and Honolulu on Oahu Island. The U. S. S. *Nero*, under command of Commander Charles Belknap, U. S. N., has been engaged since April last in a survey of the bed of the Pacific along the proposed route of the cable from the Hawaiian Islands westward to the Philippine Islands and to Japan. A preliminary report of this survey recently received, adds greatly to the knowledge of this part of the Pacific and to the data necessary before determining the exact route of the cable. This survey develops two unusual physical features along the route via Midway Island, one of these is a submarine mountain, situated a short distance westward of the Midway Islands and rising from the floor of the ocean, having a depth of 2,200 fathoms to within 82 fathoms of the surface. The second feature is one of the deepest submarine abysses yet found in the world, situated about 500 miles eastward of Guam and more than 4900 fathoms in depth. These and other obstacles which may be found, however, can be avoided in laying the cable by making suitable detours around them as is ordinarily done.

A Mid-Ocean Island Cable Station.

The great decrease in speed and increase of cost consequent upon increase of length of a single span of the cable, requires a landing station, if possible, between the Hawaiian Islands and

1. See Senate Document 188.

Guam. The longest cable yet laid and in operation is the French cable from Brest, France, to Cape Cod, Mass., which is about 3,250 nautical miles in length, and there is no question that a cable directly connecting Honolulu and Guam could be successfully laid, if no practicable landing place between these points could be obtained. This single span, however, about 3,650 nautical miles including "slack," would for all time so reduce the through speed of the cable, and so increase the original cost, as to warrant unusual expense, if necessary, in preparing and maintaining an intermediate station. In this connection the large amount of techinal evidence given before the British Pacific Cable Committee relative to the Vancouver-Fanning Island span, which is practically the same extreme length of 3,600 nautical miles, and of the utilization of Fanning Island as a station, are valuable as showing entire practicability. Although both Wake and Midway islands, which have been proposed as stations, are low atolls, rising but a few feet above high water and with little to sustain human life, yet either of these places is equal, if not superior, to Fanning Island. Further careful surveys will be necessary before the exact route west from the Hawaiian Islands to Guam can be finally determined. Fortunately for this enterprise, the annexation of the Hawaiian group brought under the sovereignty of the United States eleven or twelve small, rocky or sandy islands extending to the northwestward about 1,800 miles from Honolulu. These must be surveyed and considered from the cable standpoint before a final selection of route can be made.

The distances in nautical miles along two provisional routes, including ten per cent. for "slack" in laying, are as follows:

San Francisco to Honolulu	2,286 miles.
Honolulu to Midway Island	1,254 "
Midway Island to Guam	2,523 "
Guam to Dingala Bay, P. I.	1,496 "
Total via Midway Island	7,559 "
San Francisco to Honolulu	2,286 miles.
Honolulu to Wake Island	2,205 "
Wake Island to Guam	1,435 "
Guam to Dingala Bay, P. I	1,495 "
Total via Wake Island	7,422 "

In Appendix I. are shown the great circle and rhumb line distances involved, and the geographical positions used.

Cost, Maintenance and Operation.

The cost of laying cable depends mainly upon the materials used in its construction, and therefore fluctuates with prices current. The outer coverings are much the same in all specifications, according to the conditions of the case, but the copper conductor and the gutta-percha insulation vary with the speed required over the cable. Since the length of the longest section of the proposed Pacific cable is approximately equal to each of several of the Atlantic cables, the type of the cable to be used for this section, and the speed obtainable are subject to a close estimation.

Of the eleven cables spanning the north Atlantic, the Anglo-American Company's cable laid in 1894, and the Commercial Cable Company's cable No. 3 laid also in 1894, have the greatest speeds. The former contains 650 lbs. of copper and 400 lbs. of gutta percha, and the latter 500 .lbs copper and 320 lbs. gutta percha per nautical mile. Either of these types of cable would give good results and no cables of less equivalent speed should be considered.

The following conservative estimate is made from the evidence obtainable relative to the establishment of this enterprise by the government on a sound financial basis:

Maintenance and Repair Per Annum.

Annual expenses of two cable repair ships	$200,000.
Annual expense for new cable, assuming entire cable to be replaced in 40 years, or 200 miles per year	200,000.
Working expenses	125,000.
Reserve fund, and interest on capital	400,000.
Total net earnings of cable required	$925,000.

This provision for laying 200 miles of new cable per year should perpetually maintain the value of the cable as an asset, and the reserve fund further provides that the entire capital shall be replaced at the end of fifty years, or what is equivalent, that a sinking fund shall be established, which, at the end of fifty years will be sufficient to lay an entire new cable in addition to the permanent maintenance of the original one, so that at the end of fifty years, two working cables will be provided for.

Taking average conditions for long cables ten years ago, the annual expenses for maintenance and repair, *e. g.*, for new cable required, etc., and not including the fixed expenses such as the repair ships, was about $30 per nautical mile. The great

advancement in cable manufacture since has reduced the average repair rate materially, but assuming this rate as it then averaged, the total charge to this item is practically the same as that given by the independent supposition above.

At present there is no first-class cable ship in the world flying the American flag and which would therefore be under the control of the United States in time of war. It should be the policy of the United States, whether the Pacific cable is laid by the government or by a subsidized company, to require that two complete cable repair ships, one, at least, also capable of laying long cables, equal to any yet constructed for these purposes, and flying the American flag, be stationed in the Pacific ocean.

Speed.

The "speed" of a cable is a somewhat loose expression and depends upon the voltage used, the particular apparatus employed in working the cable, as well as the design and construction of the cable itself, and the skill of the operators. Besides, there is a considerable margin between a speed which will do for press matter in ordinary plain language, and the speed permitted for code and cipher messages.

"Speed" expressed in words per minute is misleading, since five letter words are frequently taken as the basis, whereas in actual practice a telegraphic word averages about eight letters, the increase being due to code words, and the omission of many conjunctions and prepositions when messages are sent in clear. A better method of expressing speed in cabling is in standard letters of a certain number of signals each, transmitted per minute, so that experienced operators can certainly and easily read them. The practical speed is the proportion of the maximum speed which remains after deductions are made for the words transmitted for which no revenue is received, on account of service prefixes, etc., repetitions, errors, corrections, necessary interval between messages, administrative messages connected with traffic, etc. In determining the deductions from the maximum speed to obtain the practical speed in paying words per minute there is little evidence at hand. In the perfected management of the Atlantic cables where keen competion exists, this "dead" traffic has been reduced to sixteen or seventeen per cent. of the whole. For a Pacific cable an amount of "dead" traffic as great as 30% at first is estimated, and this could probably

be reduced in successive years as it has been in the Atlantic traffic. Assuming 30% for "dead" traffic, and an increase of 90% of speed for duplex working it is estimated that the maximum capacity of the cable in total paying code words, of eight letters each, would be about 11,800,000. per annum. The cost of maintenance and operation, etc., as above being $925,000 per annum, the average cost of transmission per telegraphic word is about .08 cents.

In connection with speed of cabling it may be said that the opinions of the best cable experts in the world as to the theoretical speed obtainable from a given cable over a given distance differs so widely as to inspire caution in making all estimates.

The present commercial rate from Washington to Manila is $2.38 per word, Government rate $2.255 per word, and the rate for "right-of-way" messages three times the normal rate.

It is seen that at the present commercial rate to Manila, after allowing for present land rates to San Francisco, the proposed cable is required to operate less than fifty minutes per day in order to earn the income of $925,000.00 per year. Allowing the present rate to be reduced one-half, the cable would have to work less than two hours daily. If the rate per code word, of an average of eight letters, is placed at fifty cents from San Francisco to Manila, then, upon the above supposition, the cable need operate daily less than four hours to meet expenses.

Assuming the cable to be interrupted as much as one-quarter of the entire time, the figures above still appear striking.

The desirability of the cable from an economic standpoint seems unquestioned. The Secretary of War says in his annual report:

"The cable tolls of the War Department messages alone to and from the Philippines for the last five months have averaged monthly a rate of over $325,000.00 a year."

This alone equals the interest at three per cent on the sum of $10,845,000. It is reasonable to assume that the despatches of the oher departments of the Government would at eleast increase this amount by one-quarter, which would make the present Government cable tolls to and from the Philippines equal to the interest a three per cent. on approximately $13,500,000. Fully 90% of this sum goes to foreign corporations while all Pacific cable expenditures would remain in the United States.

In an ocean cable enterprise the largest item of annual expense is invariably the interest on the capital invested. No one can borrow money at a less rate than the United States Government, and furthermore as a Government enterprise, the cable is at once relieved from earning any sums for dividends, and is only required to maintain itself in a prudent and sound financial condition.

Proposed Management of the Cable as a Government Enterprise.

Assuming that the proposed Pacific cable will be established by the Government, opportunity will be presented in this new and unoccupied field of the Pacific, unfettered by precedent and obligations, to introduce such radical changes in the policy and business management of the enterprise as will operate advantageously to the whole people who are directly concerned, and for whom the cable is primarily built. Private corporate management naturally aims at large dividends for its stockholders. It is a matter of statistics that in cabling throughout the long distances involved in the East, out of every one hundred messages sent, ninety-nine are purely commercial in character, and one of private nature. Cabling throughout the world is so expensive that it is only resorted to for urgent commercial purposes. The present tariff rates strictly limit the kind of traffic offered, and prohibit all other than that of the most urgent nature, and are sufficiently high to keep the long cables actually idle for a considerable portion of each twenty-four hours. The enormous volume of the present mails indicate that the world's cable plant could be duplicated many times and all kept full to overflowing if the cable rates were sufficiently reduced.

Electricity the Ideal Medium for Transmitting Intelligence.

The triumphs of science in the last half century have been nowhere more exemplified than in the enormous strides made in the facility of transmitting intelligence. The mails, the telegraph and the telephone are civilizing the world. Perfect as is the mail system of to-day, a monument to organization, yet, its swiftest messenger—steam—is so far outstripped either on land or sea by the practically instantaneous electric current, that the tendency year by year is to put more of the world's business "upon the wire." The time is fast approaching, let us hope, when a

telegraph and cable letter service at rates comparable with present postage rates will be realized throughout the world, with its consequent revolutions in business and social methods. Time has an international money value. The fastest mail express, or the swiftest ocean mail ship, are as naught compared with the velocity of the electrical impulse which practically annihilates any terrestrial dimension. As the distance increases, electricity surpasses steam in a continuously increasing ratio. In the case of a message to be sent across the street, probably there is no more efficient and satisfactory method than by a mail delivery messenger, but if this message is to be sent half way around the earth, the minutes required by the telegraph run into weeks and months by the slow process of the mails. Steam time is directly a function of the distance to be traversed, and from the nature of things must require twice as long to go two miles as one. If then the cable saves six days between Europe and America, it will save more than twice this time between America and the East, and is from this point of view correspondingly important and necessary. Since electricity so far outstrips any other known vehicle for transmitting intelligence it must eventually carry all the important information and practically take from the present mails more and more of the most urgent letters.

Continuous Use of the Cable Proposed.

With a Pacific cable in operation, and possessing such immeasurable advantages over the mail, how can any management be entertained which does not aim at the use of the cable continuously to its fullest capacity? Cable property is peculiar in that it does not, like mechanical machinery possessing moving parts deteriorate with use, and its life is not therefore dependent upon the amount of traffic transmitted. The ordinary manufacturing plant is usually not operated continuously because the coal consumption, the wear and tear of machinery, and the extra expense of employees—combined with the state of orders received, do not present a sufficiently attractive economical proposition. But a large cable property presents unique conditions from a purely business standpoint. The bulk of the capital invested is buried under the sea, and much the largest item to be earned is the interest on the capital. A 2000-mile line requires but two operating stations, and the annual expense of a few clerks who actually operate the plant, forms a comparatively insignificant part of the total annual expense.

In the estimate of Mr. Alexander Siemens upon the British Pacific cable in a paper at Ottawa in 1894, but 12% of the total annual expense was for operating staff proper, and this also provided for more than double the usual wages, in consideration of the isolated positions of the mid-ocean stations. Add to this the fact that what ordinarily corresponds to coal consumption, here consists of a few electric batteries, and is therefore practically nil, and also the fact that using the plant causes no deterioration, and the logical business conclusion is reached that ocean cables should be kept busy continuously. Every hour they remain idle is so much service absolutely lost. Present cable tariffs are so high as to force to idleness for a considerable portion of each twenty-four hours all of the long cables of the world. In addition the Atlantic cables are practically silent one day in seven.

In defense of the present management, too often unjustly criticized, it is submitted that cable property on the whole has been particularly hazardous and uncertain; repairs often most expensive, and a prudent management has required large sinking funds and reserves. Furthermore, the necessary traffic arrangements required with co-operating or competing companies establish precedents and form obligations not easy to suddenly change. The whole of cable history does not yet cover fifty years, but the skill and experience of the large cable manufacturers in England have brought this industry to such a state of perfection that the laying of a 2000-mile ocean cable, or its repair, in 3000 fathoms, is no longer considered a particularly hazardous undertaking. In fact, in the beginning, cable rates had to be high, and although there has been a steady decrease in rates to the present, as the technical side of the business has become more stable and certain, yet it is believed that the time has now arrived when a more extensive classification and reduction can be inaugurated with advantage both to patrons and to revenues earned.

As a practical means for operating the cable continuously, it is a natural suggestion to classify the traffic offered and establish differential rates therefor as is now universally done on land lines. The same causes which have established night rates on land are much more potent in case of ocean telegraphy where the time gained and the capital invested per mile is enormously greater. It is simply a matter of paying for time. The stock exchange message where minutes are valuable should be charged

the highest rate, while the press and less urgent business messages should be classified and paid for according to the time limit called for in delivery. Since the only other competitor in the Pacific is the mail steamships where the minimum time is over two weeks, it should be easy both to create new business and to draw from the mails as desired. In handling certain classes of messages it can be distinctly agreed to deliver only within a certain number of hours or a week or even establish a low Sunday rate for certain classes of matter, and still arrive much ahead of letters sent by mail. If we have no less than four classes of matter in the present mail system by steam train, why not a classified service for an ocean cable postal system where the reasons for it are more potent?

For the fiscal year ending June 30, 1898, the amount of mail matter, letters proper, excluding all other forms of mailable material, carried in mail steamers from the United States across the Pacific Ocean for Japan, Hong Kong, Shanghai, Manila, Singapore, Cochin China, Java, and Siam was about 10,948,651 grams, representing about 1,156,176 letters. From the United States for Hawaii, 3,495,442 grams, representing about 369,072 letters. This reveals the appreciable proportion of the Pacific traffic which stops at the Hawaiian Islands, being from the above figures about 25% of the entire traffic which in 1898 left the United States for these countries. These figures are instructive as indicating that in considering the through trans-Pacific cable, the Hawaiian traffic is not entirely to be ignored, and that of the entire length of the cable, the span between California and Hawaii will continuously be required to carry a materially greater portion, and will, therefore be the first span requiring duplication.

Assuming as above that the carrying capacity of the proposed cable be equal to that of the best Atlantic cables for corresponding lengths, it is of interest to obtain in a general way the amount of traffic which can be handled across the Pacific under a management which ensures the cable being used continuously.

The proposed cable should possess a carrying capacity each way per annum of about 5,900,000 code words of eight letters and this allows 30% of the entire amount as waste or non-paying traffic. This means, of the 1,156,176 letters which in 1898 were transmitted to Japan, Hong Kong, Shanghai, Manila, Singapore, Cochin China, Java and Siam, this entire number could have been transmitted by cable, allowing for each communication

about five words of eight letters each. Since the use of code books for cable messages has so much increased that practically all cabling is now transmitted in this manner, we can reasonably take one word equivalent to five by their use, so that each communication above referred to is equivalent to twenty-five words of average length.

Means for Duplication.

All important sub-marine cables should be duplicated as soon as possible. Cables are always liable to interruption from a variety of causes, and the interruption of a single line necessarily suspends all communication. The protection of the patronage requires duplicate lines if for no other reason.

An adequate plan for a Pacific cable should consider means for the duplication of the line. In this connection an examination of the Pacific ocean, and the route of the proposed British Pacific cable from Vancouver to Australia, suggests a span of cable of international value. Reference is made to the desirability of connecting Hawaii and Fanning Island with an Anglo-American cable, operated by the governments concerned, under rules mutually acceptable. A common interest should lead to the linking together of these two great ocean telegraphic routes in the mid-Pacific.

With this single span of cable laid, which is but about 950 nautical miles in length, or but 13% of the length of either of the main lines, it results that each country has practically ensured its line against a total interruption until such other duplicate lines can be laid as the growth of the business will undoubtedly warrant.

Thus in case the British cable between Canada and the mid-Pacific should be interrupted, it would only be necessary to route the British business for Australia, arriving at Vancouver,—over the United States land lines to California to be transmitted over the United States cable to Hawaii, thence over the international span to Fanning Island, and on to Australia via the British line; or in case the American span to Hawaii is interrupted, the United States can likewise reach these islands and the East by routing traffic to Vancouver for transmission to Fanning Island, and thence to our trans-Hawaiian cable also via the international cable span.

In a similar way, in case any section of either through cable is interrupted beyond the Hawaii-Fanning span, the urgent

United States traffic can be routed from Hawaii westward via Australia and thence to the East, or the urgent British business can reach Australia via Manila.

It is believed that such a living and equitable arrangement can be effected in the working of these Pacific cable systems as would afford security to each and result in mutual traffic advantages to both enterprises. Thus there is no reason why the present Atlantic cable system and the United States land systems should not eventually serve as material feeders to and from Australasia, and likewise the British and Canadian systems supply an appreciable traffic to the Philippines and the East.

Cable Connection with the Samoan Islands.

The interests of the United States in Samoa will be more clearly defined by the acquisition of sovereignty over the island of Tutuili now reported probable. In this connection another branch of cable is suggested, which the United States could properly assist. As shown upon the accompanying map, a span of cable but 650 miles in length connecting Fiji with Apia, would thus join the Samoan group to the main British Pacific cable route and furnish cable connections for the three governments interested, viz. England, Germany, and the United States.

Conclusion.

After several years of comparatively little advance, the technical and scientific side of telegraphy has received much attention during the past two or three years, until at this moment there is no other special branch of electrical engineering which is more in evidence or promises more for the future.

By whatever method the first Pacific cable is ultimately laid, and provided that it shall appear that all of the projected cable cannot be manufactured and laid in the United States within a reasonable time, it seems plain that the encouragement of American manufacturers in the building up in the United States of a deep sea cable industry of the first-class is a wise policy for this Government.

The successful completion of the submarine cable across the Pacific will mark an epoch in the telegraph history of the world. After thirty years of consideration—technical, commercial and political—the end of this century sees this great enterprise at last seriously undertaken. The full influence which it will exert

upon the Western Hemisphere and the world in general is not easily appreciated. Strategically, the importance of this intercolonial communication and its preservation are very great. However, the Philippine question should not overshadow the larger question—the Eastern question—in the consideration of this project. Important as the cable will be as a means of joining the Philippine archipelago to the United States, its larger importance will ultimately be in the future of the commercial development between the United States and the East. In the broad extension of the Pacific trade consequent upon the completion of the Isthmian canal and the development of steamship lines plying the Pacific, the telegraph cable will naturally become an important factor. The trans-Pacific steamship lines are heavily handicapped by the absence of a direct means of telegraphy between the ports embraced in their routes. Situated on the main trade routes leading from the Isthmian canal to Asiatic ports, the Pacific cable will serve as a powerful adjunct and support to this enterprise. The two go hand-in-hand and are mutually closely related. It can be stated that there is scarcely any point in the world where there is greater need for a central cable station than in the Hawaiian Islands. Geographically situated at the military and commercial strategic position of the North Pacific ocean, it will ultimately serve as the distributing center of ocean communication between the two hemispheres, as well as to various island groups of the Pacific.

As to the probable traffic to be immediately expected there is little direct evidence at hand, since the waters spanned have never before been crossed by a submarine cable. Taking $150.00 as the average earning power per nautical mile of the long cables of the world as a basis, this project should prove a paying investment from the very first, but it is believed that this estimate, based upon the average of cables will prove under rather than above experience, particularly as this route will immediately enter as a competitor for European traffic via the Atlantic cables and United States land lines. The immediate effect of the trans-Pacific cables will be to lower the rates to the East, since European traffic will be open to competition, east and west, and the new Western route, due to the long spans and comparatively few repetitions will have an advantage.

A short span of cable of about 200 miles between Luzon and Formosa connecting with the Great Northern Telegraph Com-

pany's route through Siberia and also between Luzon and a Chinese port will bring Japan and China into direct connection not only with the North American Continent, but also by two competitive routes east and west with Europe. In fact, the laying of the Pacific cable should operate to readjust the present cable through-tariff rates throughout the world upon a lower basis.

Appendix No. 1.

PROJECTED PACIFIC CABLE.

Distances in Nautical Miles.
(United States Coast and Geodetic Survey.)

PROVISIONAL ROUTES.	Great Circle.	Rhumb Line.	Great Circle Distances + 10 per cent. slack.	Great Circle Distances + 15 per cent. slack.
San Francisco to Honolulu	2078.43	2086.86	2286.27	2390.19
Honolulu to Midway Island	1139.98	1140.95	1253.97	1310.97
Midway Island to Guam	2293.64	2299.25	2523.00	2637.68
Guam to Dingala Bay, P. I.	1359.95	1360.50	1495.94	1563.94
Totals	6872.00	6887.56	7559.18	7902.80
San Francisco to Honolulu	2078.43	2086.86	2286.27	2390.19
Honolulu to Wake Island	2004.27	2008.23	2204.69	2304.91
Wake to Guam	1304.43	1305.08	1434.87	1500.09
Guam to Dingala Bay, P. I	1359.95	1360.50	1495.94	1563.94
Totals	6747.08	6760.67	7421.77	7759.14
Guam to Yokohama	1348.05	1348.12	1482.85	1550.25

1 mile=1853.25 metres or 6080.2 feet.

Geographical Positions Adopted.

San Francisco, California, Fort Point, Golden Gate.
Honolulu, Hawaiian Islands, Harbor Light.
Midway Island, or Brooks Island, Welles Harbor.
Wake Island, center.
Guam, Fort Sta. Cruz, San Luis de Apra.
Dingala Bay, Luzon Island
Yokohama, Japan, English Naval Storehouse.

The nearest point of the main land from Honolulu is Point Arena, next Point Reyes, next Point Sur, California. Taking the positions of the lighthouses the distances to Honolulu are as follows:

From Point Arena . . . . . 2045.7 Nautical Miles.
" Point Reyes . . . . . 2057.5 " "
" Point Sur . . . . . 2078.4 " "

As evidence of the importance of particular secret manipulation during manufacture, independent of the weights of materials employed, and the measured K. R. of the finished cable, Messrs. Siemens Brothers & Company have lately issued a table of Trans-Atlantic cable speeds from which the following data is taken :

TRANSATLANTIC CABLES.

TABULAR STATEMENT OF ACTUAL AND CALCULATED SPEEDS.

Date when laid.	Designation of Cable.	Length in nautical miles.	Type of core of Deep Sea cable. Lbs. per nautical mile.	K. R. *Ohm* × *Micro-farads.* ÷ 10^6	Speeds actually obtained in regular working. 5 letter words.	Calculated speed if lengths 1,860 naut. miles.	Calculat'd speed if lengths 1,850 naut. miles and core 650/400.
			Cop. G.P.				
1873	Anglo-American.	1876	400/400	3.919	....	....	....
1874	Anglo-American.	1837	400/400	3.512	20.2 (a)	19.9	28.2
1875	Dir't United States.	2423	400/360	7.558	22.6 (b)	38.6	70.2
1879	Pouyer-Quertier.	2242	350/300	6.600	22 (c)	32.2	59.8
1866/80	Anglo-American.	1852	.....	4.632	....	....	....
1881	Jay Gould.	2518	350/300	7.834	21.5 (d)	39.8	69.4
1882	Jay Gould.	2563	350/300	8.030	21.5 (d)	41.2	71.2
1884	Mackay-Bennett (S).	2353	350/300	6.740	26	42.0	72.3
1884	Mackay-Bennett (N).	2346	350/300	6.630	26	41.8	71.2
1894	Mackay-Bennett(3rd).	2161	500/320	4.671	40 (g)	54.6	77.2
1894	Anglo-American.	1850	650/400	2.420	47.4 (e)	47.4	47.4

(a) Report of Engineers, Messrs. Clark, Forde & Co., to the Manager of the Anglo-American Telegraph Co., dated June 25, 1877.

(b) Report of Engineers, Messrs. Clark, Forde & Co., to the Manager of the Direct United States Cable Co., dated June 25, 1877.

(c) Report of the Engineer-in Chief, Mr. von Chauvin, to the Pouyer-Quertier Cable Co., dated June 15, 1880.

(d) Report of Dr. Muirhead to Mr. von Chauvin, Representative in London of the Western Union Telegraph Co., dated July 10, 1883.

(i) Special trial of code words, 18 words per minute } mean
(ii) Press messages, usual rate, 25 " " " } 21.5
(iii) As many as 135 letters per minute have been observed to pass at times without requiring repetition.

(e) "Electrician" dated October 12, 1894.

(g) From a letter from Mr G. G. Ward, Vice-President and General Manager of the Commercial Cable Co., dated May 10, 1895,

Appendix No. 2.

Trans-Pacific Telegraph Cable Survey.

[*From Annual Report of Chief of the Bureau of Equipment, Navy Department, November, '99.*

A practicable route for a submarine-telegraph cable was established between San Francisco and Honolulu some years ago.

In order to continue the survey of the route from Honolulu to the Philippines, the U. S. S. *Nero*, under command of Commander Charles Belknap, U.S.N., was very thoroughly fitted out and equipped for deep sea exploration at the navy-yard, Mare Island, during the early part of the present year. The *Nero* is a large steam collier purchased for use during the late war, and on account of great steaming radius was admirably adapted to make the survey. After a careful consideration of the subject, it was decided that the best route westward from Honolulu to the Philippine Islands was by way of the Midway Islands and Guam, landing the cable at a convenient point on the east coast of Luzon as near as possible to the latitude of Manila. It was also decided as desirable to survey a route from Guam to Yokohama. Elaborate instructions for the survey were prepared. The plan of the survey, which is represented on the accompanying chart, consists in carrying direct lines of soundings, taken at alternate intervals of 10 and 2 knots, from Honolulu to the Midway Islands, thence to Guam, and thence to Luzon, and also from Guam to Japan. The return course to be pursued is a zigzag line passing back and forth to equal distances on each side of the route followed in going to the westward, with soundings at intervals of 20 knots at the turning points.

The *Nero* sailed from San Francisco for Honolulu on the 22d of April. She sailed from Honolulu to commence her work on the 6th of May. On the 22d of May she had completed a single line of soundings to the Midway Islands, by July 4 to Guam, and by August 1 to Luzon.

Along this route, which is 4,812 knots in length, 853 soundings were taken. The characteristics of the bottom soil and the temperature of the surface water were observed at each sounding station, and these, together with the meteorological record and the frequent observations of specific gravity, bottom temperature, and the currents of the ocean, besides their value in laying a submarine cable, will form an important contribution to the physics of the Pacific ocean.

Two offsets from the projected great circle route between the Midway Islands and Guam were found to be necessary in order to avoid obstacles to a successful laying and operation of a tele-

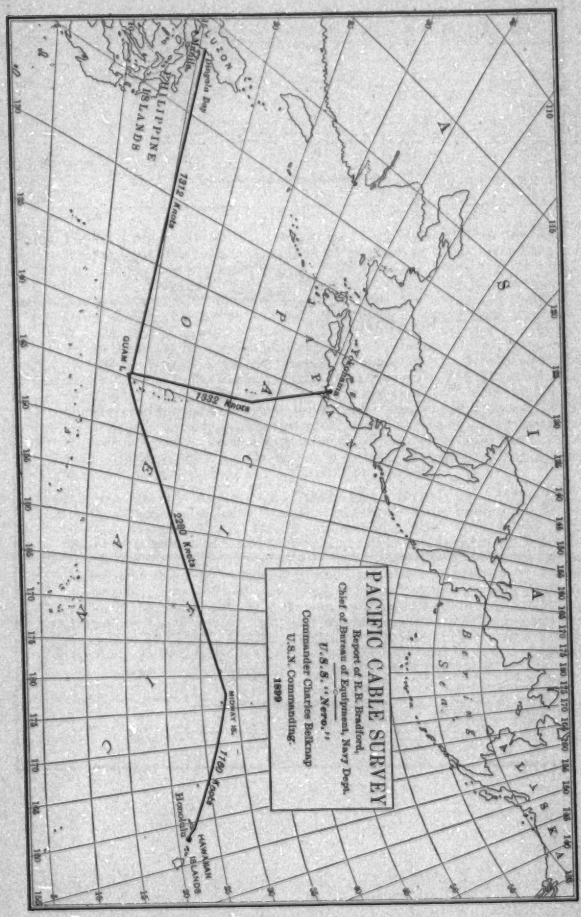
graph cable. The first of these obstacles encountered is a submarine mountain situated a short distance westward of the Midway Islands and rising from the floor of the ocean, which here sinks to a depth of 2,200 fathoms, to within 82 fathoms of the surface. The second obstacle is one of the deepest submarine abysses yet found in the world, situated about 500 miles eastward of Guam, and sinking to a depth of more than 4,900 fathoms.

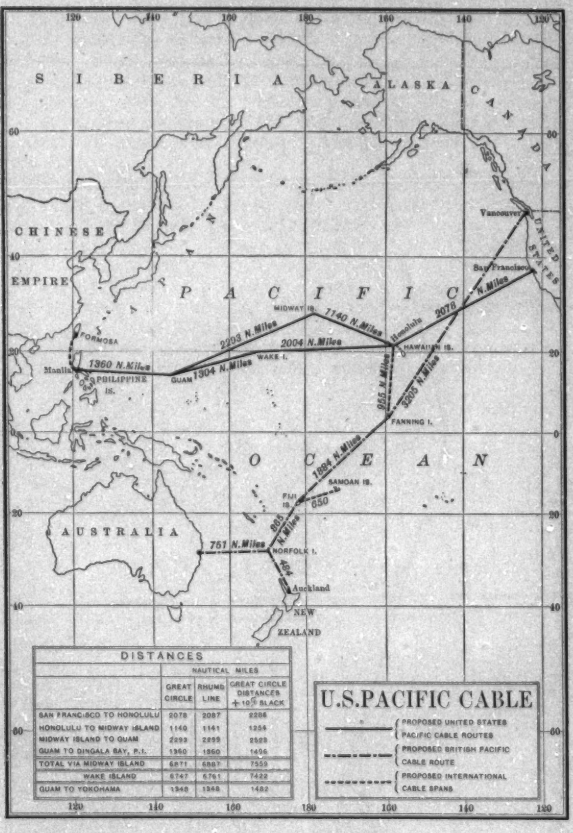
Reports have been received of the preliminary line of soundings from Honolulu to Luzon, and they indicate that the route which is being surveyed will prove entirely practicable.

No reports of the soundings taken on the return trip or of any soundings from Guam to Yokohama have been received.

Owing to illness, Commander Charles Belknap, U.S.N., was relieved from the command of the *Nero* at Manila by Lieut. Commander H. M. Hodges, U.S.N.

The expenses of this survey, so far as this Bureau is concerned, has been entirely defrayed from its current appropriations.


PACIFIC CABLE SURVEY
Report of R.R. Bradford,
Chief of Bureau of Equipment, Navy Dept.
U.S.S. "Nero,"
Commander Charles Belknap
U.S.N. Commanding.
1899
PHILIPPINE ISLANDS
Manila
Subig Bay
1912 Knots
GUAM I.
1932 Knots
2380 Knots
MIDWAY Is.
1160 Knots
HAWAIIAN ISLANDS
Honolulu
PACIFIC OCEAN


SIBERIA
ALASKA
CANADA
CHINESE EMPIRE
PACIFIC OCEAN
AUSTRALIA
NEW ZEALAND
UNITED STATES
Vancouver
San Francisco
Honolulu
HAWAIIAN IS.
MIDWAY IS.
WAKE I.
GUAM
PHILIPPINE IS.
Manila
FORMOSA
FANNING I.
SAMOAN IS.
FIJI IS.
NORFOLK I.
Auckland
2093 N.Miles
2004 N.Miles
1360 N.Miles
1304 N.Miles
1140 N.Miles
2078 N.Miles
955 N.Miles
3593 N.Miles
1684 N.Miles
650
965 N.Miles
761 N.Miles
994
DISTANCES
NAUTICAL MILES
GREAT CIRCLE
RHUMB LINE
GREAT CIRCLE DISTANCES +10% BLACK
SAN FRANCISCO TO HONOLULU 2078 2087 2286
HONOLULU TO MIDWAY ISLAND 1140 1141 1254
MIDWAY ISLAND TO GUAM 2293 2295 2523
GUAM TO DINGALA BAY, P.I. 1360 1360 1496
TOTAL VIA MIDWAY ISLAND 6871 6967 7559
WAKE ISLAND 6747 6761 7422
GUAM TO YOKOHAMA 1348 1348 1482
U.S.PACIFIC CABLE
PROPOSED UNITED STATES PACIFIC CABLE ROUTES
PROPOSED BRITISH PACIFIC CABLE ROUTE
PROPOSED INTERNATIONAL CABLE SPANS

DIED.

GREENE:—At Schenectady, N. Y., January 8th, 1900, by accidental drowning, Samuel Dana Greene, Assistant General Manager of the General Electric Co. Mr. Greene was born in New York City, on October 24th, 1864. Graduated from the U. S. Naval Academy in June, 1888, after a regular four years ecurse, followed by a special course of one year at the U. S. Naval Torpedo Station at Newport, R. I. He resigned from the navy in June, 1887, and went with the Sprague Electric Railway and Motor Co. as Assistant Electrician and subsequently became Chief Engineer. In 1889, he became Assistant General Manager of the United Edison Mfg. Co., and afterwards Manager Central Districts. When the General Electric Co. was organized he was appointed Assistant to 2d Vice President, and General Manager Sales Department, and subsequently Assistant General Manager. Mr. Greene was elected an Associate Member of the INSTITUTE September 20th, 1893, and transferred to full membership April 18th, 1894. In May, 1899, he was elected one of the Managers of the INSTITUTE which office he held at the time of his death.

HAMBLET:—At his late residence, 20 Sidney Place, Brooklyn, on January 2d, 1900, of pneumonia, James Hamblet, Manager, of the Telegraphic Time Service, Western Union Telegraph Company, New York City. Mr. Hamblet was born in Boston, June 16th, 1824, was engaged by William Bond & Sons as electrician abont 1852. He subsequently became a member of the firm of Edmonds and Hamblet, manufacturers of fine mechanism. Since 1878, Mr. Hamblet has been identified with the Western Union Telegraph Company. He was elected an associate member of the INSTITUTE November 1st, 1887, and was transferred to full membership December 6th, 1887. In May, 1891, he was elected a Manager of the INSTITUTE, continuing until the expiration of his term in 1894, when he was elected a Vice-President for the usual term of two years.

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